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OF THE

MANUFACTURE AND PROOF

OF

GUNPOWDER

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HANDBOOK

OF THE

MANUFACTURE AND PROOF OF GUNPOWDER,

AS CARRIED ON AT THE

Royal Gunpowder Factory, Waltham Abbey.

BY

CAPTAIN F. M. SMITH, ROYAL ARTILLERY,
ASSISTANT SUPERINTENDENT.

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PREFACE.

THE following short treatise is intended as a guide to officers who wish to make themselves acquainted with the manufacture and proof of gunpowder, as now carried on in the Royal Gunpowder Factory. With the exception of a pamphlet written in 1867 by the late Major J. Fraser Baddeley, then Captain-Instructor in the factory, and a brief series of notes compiled by Captain O. H. Goodenough from an unpublished pamphlet of Colonel Boxer's and other sources, for the use of the gentlemen cadets, there is no work which gives an account of the system of manufacture and proof now practised at Waltham Abbey.

It must be admitted that there are many points connected with the manufacture and proof of gunpowder which are as yet imperfectly understood. But there is every reason to believe that the labours of the Committee on Explosives, who have at their command new and delicate means for proof and examination, will throw sufficient light on all matters of practical importance. The following pages have, however, been specially written with the view of showing not only what has been done, but what still remains to be done in each department of the manufacture and proof of gunpowder for Her Majesty's service.

Royal Gunpowder Factory,
24th December 1870.

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CHAPTER I.

INTRODUCTION.

THE following pages are exclusively devoted to a description of the work actually performed in the Royal Gunpowder Factory. No attempt has been made to compile from other sources anything like a history of gunpowder; but a list of works is subjoined, from which those who are interested in the archæology of the subject may obtain all the information of which they are in search. Nor has the chemistry of powder been fully worked out, as that branch of the subject belongs to pure chemistry.

But a few words of introduction are necessary. Gunpowder, an intimate mixture of saltpetre, sulphur, and charcoal, is said to have been known and used in the earliest ages, principally amongst the Eastern nations. It is asserted that a code of Indian laws, supposed to have been compiled in the time of Moses, contains reference to cannon and guns, and the Chinese lay claim to the invention of powder at a very early period. Writers who claim such a fabulous antiquity for the substance maintain that if Schwartz or Roger Bacon, between whom the merit of its discovery has, until recently, been considered to lie, really invented gunpowder for themselves, it was only a re-discovery of what had been known thousands of years before. Now, although substances composed principally of saltpetre, and resembling gunpowder in composition, may have been used in the East at a very early period, it appears extremely improbable that gunpowder proper was known and used as such till comparatively recently.

The deflagrating properties of saltpetre, which is found as a natural product in many parts of Asia, must have attracted early attention, and its employment as an ingredient of burning compositions could not fail to become general. But there can be little doubt that such compositions, though used in warfare, were incendiary rather than explosive in their action. It is too much to believe that the use of firearms, which would have given one nation such an immense advantage over another, could ever have been known and afterwards forgotten for centuries. Modern interpretations and ideas must have been attached to the terms used in ancient MSS., which bear no such meaning; the "fire-arms" of the Eastern nations were nothing more than darts or arrows carrying a quantity of burning composition attached to them. Even if the substance itself was known thousands of years ago, there is comparatively little interest attached to it till it came to be used in guns; and as the use of firearms in Europe dates from about the beginning of the fourteenth century, it may be safely stated that their employment in other parts of the globe could not have been general at any period much anterior to that date. Before that date there is as little interest attached to gunpowder as to the history of steam before the days of Savory, Newcomen, and Watt.

Previous to the reign of Queen Elizabeth most of the gunpowder used in England was imported from abroad; but about 1590 George

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Evelyn, grandfather of the celebrated John Evelyn, of Wootton received a license to set up powder works at Long Ditton and Godstone. The Evelyns are stated to have brought the art of gunpowder-making from Flanders. Soon afterwards they were appointed sole makers of gunpowder in the south of England, on condition of delivering into the royal stores every year a certain quantity of "good and serviceable corned gunpowder." The mills at Faversham, afterwards for a long period a Royal factory, were established about the same time as those of the Evelyns, though the latter were of the greatest importance.

It appears, however, that the Royal Factory at Waltham Abbey can boast of as great an antiquity as either of the above. For in 1561 (*Calendar of State Papers: Foreign Series*) John Thomworth of Waltham was in treaty on behalf of the Queen [Elizabeth] for the purchase of saltpetre, sulphur, and bow-staves for barrels. The saltpetre was offered to him at 3*l.* 10*s.* the cwt., which he declares to be too dear. Again, Fuller, who was collated to the living of Waltham in 1641, states (*English Worthies*, I. 338): "It is questionable whether "the making of gunpowder be more profitable or more dangerous; the "mills in my parish have been five times blown up within seven years, "but, blessed be God, without the loss of any one man's life."

From the parish register, under date 4th October 1665, it appears that Thomas Gutridge and Edward Simons were "killed with a powder mill," and that on 27th November 1720 Peter Bennet also met his death from an explosion.

Fifteen years later, viz., in 1735, Farmer, in his *History of Waltham Abbey*, gives a view of the factory, then the property of John Walton, Esq. A list of the various houses and buildings is given, amongst which are several horse-mills, stamping-mills, and bumb-mills (?). The horse-mills were probably similar to the incorporating mills now in use. There are also "sun-stoves or drying leads" for drying powder by solar heat.

The factory was acquired by government in 1787,* for in September of that year Major (afterwards Sir William) Congreve, was directed by the Duke of Richmond, Master General of the Ordnance, to engage fourteen or fifteen of the best of Mr. Walton's workmen to continue in the factory. At this date stone runners and beds were in use for the process of incorporation, but all of them appear to have been worked by horse power. The Royal Factory at Faversham was at this time also under Major Congreve's control, and the factory at Ballincollig was also in the hands of government.

In 1791 double horse-mills are spoken of.

In 1793 Major Congreve was ordered to Flanders to command the force of artillery.

In 1796 powder appears to have been regularly sent from Waltham Abbey to Purfleet for proof, as recently. Many complaints were made as to its quality.

In 1801 the horse corning-house at Waltham Abbey exploded, killing nine men and four horses. A committee of the Royal Society visited the works in consequence, to examine and report on the possibility of danger arising from electrical excitation, caused by walking or rolling barrels on the leather-covered floors, or by the use of silk-covered dusting reels. The committee reported that there could be no danger from such causes.

In 1804, there were government cylinder works in connexion with Waltham Abbey, maintained at Fisher's Street and Farnhurst in Sussex,

* The lands, however, were not finally purchased till 1795.

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for the manufacture of charcoal. These were kept up for a number of years.

In the same year occurs the first mention of iron runners and beds for incorporating mills, which were first used in Scotland. The yield of the factory at Waltham Abbey was, at this period, 20,000 barrels* per annum; but to produce this quantity the mills required to be kept going on Sundays.

In 1811 occurred a disastrous explosion at the lower island works of a press-house, corning-house, and reel-house, causing much loss of life and property; in consequence of which a recommendation was made the following year by the engineers who were appointed to consider the best plan of re-establishing the works destroyed, that Bramah presses should in future be used for pressing powder, and that a machine might be contrived to break the press cake more gradually. This no doubt led to the invention of the granulating machine by Sir William Congreve.

In 1814 water power was ordered to be used instead of horse power, as formerly.

In 1816 a new granulating machine on Sir W. Congreve's principle was placed in the lower island works.

In 1825 the Royal Factory at Faversham was sold; this was followed by the sale of the factory at Ballincollig, nine years later.

In 1837 an improvement on the granulating machine, invented by Mr. Charles Wilks, storekeeper at Purfleet, formerly superintendent at Ballincollig, was tried, but does not appear to have led to any result.

In 1843 a dreadful explosion occurred at Waltham Abbey of two corning-houses, press-house, and a reel-house, attended with the loss of seven lives. It originated in a building where one of the old corning-machines with shaking frames was at work, which was of course totally destroyed. No machine of this kind has been used in the factory since. Professor Faraday visited the works soon after, along with Colonel Cockburn, then Director of the Royal Laboratory, to report on various matters connected with the safety of the buildings.

In 1858 Sir W. Snow Harris, F.R.S., after an inspection of the factory, drew up a report for a system of lightning conductors for all the houses in it.

The factory as it at present stands contains 32 pairs of runners, some driven by water and some by steam, and can therefore incorporate materials for about 27,580 barrels of R.L.G., or 13,690 barrels of R.F.G., per annum. It is managed by a superintendent, an assistant superintendent, (who have charge of the entire details of manufacture, there being no official corresponding to the manager in other War Office manufacturing establishments,) a master worker, master refiner, and chief foreman of machinery, and about 150 men.

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* Probably of 90 lbs. each.

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LIST OF WORKS RELATING TO GUNPOWDER.

NOTE.—Most of the older works on fire-arms and military subjects contain descriptions of the manufacture of gunpowder. I have not had an opportunity of collating the whole of the books in the following list, which contains only books relating exclusively (or chiefly) to gunpowder and its ingredients.

1. V. Biringuccio. De la Pirotechnia. 4to. Venice, 1540.
2. Whitehorne. Certain waies for the ordering of Souldiours, &c.; and how to make Saltpetre, Gounpowder, &c. London, 1588. 4to. (In Royal Artillery Library.)
3. Hanzelet. Recueil de plusieurs Machines militaires, &c. 1620.
4. Boillet Langrois. Modelles artifices de feu. 1620.
5. Kruger. Chemical Meditations on the Explosion of Powder (in Latin). 1636.
6. Collado. On the Invention of Powder (in Spanish). 1641.
7. The true way to make all sorts of Gunpowder and Matches. 1647. (In Royal Artillery Library.)
8. Hawksbee. On Gunpowder. 1686. (In Royal Artillery Library.)
9. Winter. On Gunpowder. (In Latin.)
10. Stahls. On the Nature and Utility of Saltpetre. (In German.) Stettin and Leipsic. 1748. 12mo. (In Royal Artillery Library.)
11. D'Antoni. Esame della Polvere. Torino. 8vo. 1765. (In Royal Artillery Institution Library.)
12. D'Antoni. Examen de la Poudre; de l'Italien par M. le Vicomte de Flavigny. Amsterdam, Geneva, and Paris. 8vo. 1773. (In Royal Artillery Institution Library.)
13. Tronson de Coudray. Mémoire sur la meilleure Méthode d'extraire et de raffiner le Saltpêtre. Upsal, 1774. 8vo. (In Royal Artillery Library.)
14. Receuil de Mémoires et d'Observation sur la Fabrication de Saltpêtre. Paris, 1779. 8vo. (In Royal Artillery Library.)
15. D'Antoni. Treatise on Gunpowder, from the Italian of d'Antoni, by Captain Thomson, R.A. London. 8vo. 1789. (In Royal Artillery Institution Library.)
16. Rapport, Instruction, et Arreté du Directoir executif sur l'eprouve emmagazinement, et transport des Poudres de guerre. Paris. 4to. 1799. (In Royal Artillery Library.)
17. Cossigny. Recherches physiques et chémiques sur la Fabrication de la Poudre à canon. Paris, 1807. 8vo. (In Royal Artillery Library.)
18. Bottée et Riffault. Traité de l'Art de fabriquer la Poudre à canon. Paris, 1811. 4to. With atlas of plates, obl. 4to. (In Royal Artillery Library.)
19. Renaud. Instructions sur la Fabrication de la Poudre approuvée par le Ministre de la Guerre. Paris. 8vo. 1811. (In Royal Artillery Library.)
20. Sir W. Congreve. Statement of Facts relative to Savings and Improvements in the Manufacture of Gunpowder at the Royal Mills since 1783. London. 8vo. 1811. (In Royal Artillery Library.)
21. Fraxno. Tratado de la Teoria y Fabricacion de la Polvora en general. Segovia, 1817. (In Royal Artillery Library.)

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22. Sir W. Congreve. A short Account of Improvements in Gunpowder made by Sir W. Congreve. London. 8vo. 1818. (In Royal Artillery Library.)
23. Coleman. On the Manufacture and constituent parts of Gunpowder. (Phil. Mag. vol. 9.)
24. J. Braddock. Memoir on Gunpowder. London. 8vo. 1832. (In Royal Gunpowder Factory Library.)
25. Omodej. Dell' origine della Polvere da guerra, &c. 1834.
26. Proust. Mémoires sur la Poudre à canon. Extrait du *Journal de Physique*. Paris. 4to. 18 .
27. Expériences sur les Poudres de guerre faites à Esquerdes dans les années 1832–35. (Pamphlet in Royal Artillery Library.)
28. Timmerhans. Description des divers Procédés de la Fabrication de la Poudre à canon. Paris. 8vo. 1839. (In Royal Artillery Library.)
29. Mordecai. Reports on Experiments with Gunpowder in Washington Arsenal in the years 1843–4. Washington. 8vo. 1845. (In Royal Artillery Institution Library.)
30. Belgian Experiments on the Proof of Gunpowder in 1858. (Reported by Col. Younghusband, R.A., F.R.S.) Proceedings Royal Artillery Institution, vol. 1, p. 110–3.
31. Abel. On some Phenomena exhibited by Gun Cotton and Gunpowder under special conditions of exposure to heat. (Proceedings of Royal Society, vol. .)
32. La Cabane. De la Poudre à canon et de son introduction en France. Paris. 8vo. 1845. (In Royal Artillery Library.)
33. Macculloch. On Gunpowder. Suppl. Encycl. Britann. vol. 6.
34. Napier. Observations on Gunpowder. Transact. Royal Irish Academy, vol. 2.
35. Jacob. Practical Hints on the Proof of Gunpowder. (Printed by order of Bombay government.) 8vo. 1846. (In Royal Gunpowder Factory Library.)
36. Baddeley. Pamphlet on the Manufacture of Gunpowder as carried on at the Government Factory, Waltham Abbey. Waltham Abbey. 8vo. 1857. (In Royal Gunpowder Factory Library.)
37. Règlement sur les épreuves des Poudres dans les Etablissements du service des Poudres et Saltpêtres. Paris. Imp. imperiale. Sm. folio. 1857. (In Royal Gunpowder Factory Library.)
38. Anderson and Parlby. Sketch of the Mode of manufacturing Gunpowder at the Ishapore mills in Bengal, with record of experiments, &c. London. 8vo. 1862. (In Library of Royal Gunpowder Factory.)
39. Napoleon. Études sur le passé et l'avenir de l'Artillerie. Vol. 3. Paris. 4to. 1862. (In Royal Artillery Institution Library.)
40. Von Karolyi. On the Products of the Combustion of Gun Cotton and Gunpowder. (Phil. Magazine. Oct. 1863.)
41. Snow Harris. Principle and Instructions relative to the application of Lightning Conductors to Powder Magazines and other buildings. (Occasional papers, Royal Artillery Institution, vol. 1, p. 55.)
42. Snow Harris. Letter on a System of Lightning Conductors for Waltham Abbey. (Occasional papers, Royal Artillery Institution, vol. 1, p. 129.)
43. Bunsen and Schischkoff. On the Chemical Theory of Gunpowder. (Occasional papers, Royal Artillery Institution, vol. 1, p. 297–318.)

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CHAPTER II.

THE SALTPETRE REFINERY.

CONTENTS.—The ingredients for the manufacture of powder always refined and prepared at Waltham Abbey.—Reason for this.—East Indian saltpetre alone used at the Royal Factory.—Artificial saltpetre.—Price of the East Indian salt.—The grough salt: its refraction.—Rationale of the refining process.—List of apparatus and fixtures required.—Description of the process: 1. Solution; 2. Filtering; 3. Crystallizing; 4. Washing, testing, and drying for store.—Elimination of the impurities from the mother liquor.—Washings.—The refuse salts.—Conversion of the chloride of potassium in the refuse into nitrate of potash.—Scraping and washing of the saltpetre bags, and extraction of saltpetre from damaged powder.—Annual loss in refining saltpetre.—Daily routine of duties in the saltpetre refinery.

THE ingredients for the manufacture of gunpowder are supplied to the Royal Factory at Waltham Abbey in the rough state, and are refined and prepared for use there. In many private factories it is the custom to purchase the saltpetre and sulphur refined and ready for conversion into gunpowder, and charcoal ground or unground; but the opposite course has always been followed at the Waltham Abbey Works, with two special objects:—1st, of ensuring, as far as possible, uniformity of results in manufacture; and 2nd, safety in carrying it on. As regards the former of these, it is manifestly useless to attempt to obtain powder possessing uniform qualities, unless measures are taken to ensure the uniform purity of its constituent elements; and although the presence of chemical impurities may be readily detected in samples of refined saltpetre and sulphur supplied by contract, and though it might be possible to devise a series of practical tests for the various physical qualities of different descriptions of charcoal obtained by purchase, there can be no guarantee for the purity of the former, and uniformity of the latter, equal to that of careful supervision during the actual processes of preparation and refining. A manufacturer who refines his own saltpetre and sulphur, and burns his own charcoal, has means of ensuring the purity and uniformity of the ingredients which he makes use of, far superior to that of any system of testing, however careful. The additional security against accidents in the course of manufacture, gained by careful exclusion of all foreign matters from the ingredients during the processes of refining, is of even greater consequence in the manufacture of gunpowder. The question, how far the too frequent explosions in powder factories are dependent on the presence of minute particles of foreign bodies introduced into the ingredients after refining, *and before they come into the hands of the mixer*, has not received the attention which it deserves. But it is too often found that though care be taken to exclude any fragments of sand, grit, &c. from the powder from the time it leaves the mixing house till the time that it is finished, the same vigilance is not exercised in excluding minute particles of foreign substances from the unmixed ingredients, by which negligence the subsequent precaution is altogether thrown away. It may at first sight appear an excess of caution

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that men engaged in removing moist refined saltpetre from the refinery to the mixing house, should be as scrupulously careful not to step into the bins where it is stored without putting on clean magazine shoes. or not to make use of any shovels, barrels, &c., but those kept specially clean and free from grit for the purpose, and to take the same precautions in handling sulphur and charcoal, the latter of which is picked over by hand piece by piece before being ground, and after that treated with the same care as the other ingredients; but a moment's reflection will show that if precautions to avoid accidents are worth taking at all, they must, to be effectual, be commenced whenever the ingredients are taken in hand, and maintained to the end of the manufacture.

The saltpetre used at Waltham Abbey is exclusively that imported from India. Various descriptions of artificial saltpetre, that is, saltpetre made by chemical processes, generally by the action of chloride of potassium upon nitrate of soda, have been tried successfully; but as there is little or nothing to be gained by employing the latter, the price of which rises and falls with that of East Indian saltpetre, and as the natural salt can be refined and freed from its impurities by a simple process, it has hitherto been preferred. It comes principally from Bengal and Oude. In these countries it occurs as a white incrustation on the soil, being also mixed with it to a considerable depth. The earth is scraped up and boiled with water, and the solution after being concentrated by the heat of the sun and evaporated by artificial heat yields impure crystals of the salt, which are largely imported into this country packed in bags of coarse sacking. In this state the salt is known as "grough saltpetre." The bags when emptied of their contents are reserved for the annual scraping and "bag-washing" which is generally carried on in summer, and consists in soaking and boiling the bags to extract the salt with which they are saturated, after which they are sold to the makers of coarse wrapping paper, for the manufacture of which they are well adapted. The price of East Indian saltpetre has varied very much within the last few years, ranging as high as 59*l.* per ton a short time during the Indian mutiny, and falling as low as 19*l.* in the present year, which is about the lowest price at which it has been sold since 1824. Of late years the price has depended very much on the importation of nitrate of soda, known commercially as "cubical nitre," from South America, that being the principal ingredient used in making the artificial saltpetre; and the recent earthquakes in that quarter of the globe have tended to raise the price of the East Indian saltpetre by hindering the exportation of the former salt. A clear description of the conversion of the nitrate of soda into nitrate of potash, by the action of chloride of potassium, will be found in Mr. Bloxam's Treatise on Chemistry, p. 416.

East Indian saltpetre, as imported, invariably contains a certain amount of organic and inorganic impurities, which must be eliminated before the salt is fit to be used for powder making. The amount of impurity present is reckoned per 112 lbs., and in good samples does not amount to 5 per cwt. and seldom exceeds 10. It is known as the *refraction* of the nitre, the term being derived from the old process used to ascertain it, viz., by fusing a small portion into a cake and examining the fracture; it has nothing to do with the optical properties of the salt. In the saltpetre market 5 per cwt. is supposed to be the standard amount of impurity, all transactions taking place on that basis, but with the understanding that if the amount of impurity be greater, a reduction is to be made in favour of the buyer, and *vice versâ*.

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The following table exhibits the actual quantities that would have to be paid for at various refractions, from 1 to 15 lbs. per cwt. (scale for 5 tons).

Refraction per cwt.	To be paid for.			Refraction per cwt.	To be paid for.		
	cwts.	qrs.	lbs.		cwts.	qrs.	lbs.
1	103	2	27	9	96	1	1
2	102	3	6	10	95	1	9
3	101	3	13	11	94	1	16
4	100	3	21	12	93	1	23
5	100	0	0	13	92	2	8
6	99	0	7	14	91	2	10
7	98	0	15	15	90	2	17
8	97	0	22				

100 tons of grough saltpetre at 19*s.* per cwt. and 5 per cwt. refraction, would cost, therefore (exclusive of brokerage), 1,900*l.* The same amount at the same rate, but with only 3 per cwt. refraction, would cost 1,935*l.* 9*s.* 1¼*d.*, ascertained as follows :—

From the table, each 5 tons at 3 per cwt. refraction represents really 5 tons 1 cwt. 3 qrs. 13 lbs., which multiplied by 20 gives 101 tons 17 cwt. 1 qr. 8 lbs. to be paid for at 19*s.* per cwt., which gives the sum to be paid as above.

The impurities generally present in the grough saltpetre as imported are the chlorides of potassium and sodium, the sulphates of potash, soda, and lime, sand, and organic matter.

The following is a copy of three analyses of specimens of grough saltpetre :—

Moisture - -	1·60	1·59	1·74
Sand - - -	·10	·21	·25
Sulphate of soda -	—	·78	3·21
Chloride of sodium -	1·00	·37	·85
Saltpetre - -	97·30	97·05	93·95

The process employed at Waltham Abbey for eliminating these impurities is a very simple and effectual one, and was first introduced and practised in France. It is important that its *rationale* should be clearly understood before its description is attempted.

Rationale of the Refining Process.—The principle on which the process depends is that saltpetre is greatly more soluble in hot than in cold water, while the impurities generally found in it do not present the same disparity in their solubility at different temperatures. Thus a saturated cold solution of grough saltpetre, will, as its temperature is raised, take up a much greater additional quantity of saltpetre proportionately than it will of the other salts present. Hence, if a boiling saturated solution of the impure salt be made and allowed to cool, it will deposit the excess of saltpetre, and retain the other salts in solution. Boiling water will take up 39·61 parts of chloride of sodium and about 240 of saltpetre. Water at the temperature of 70° will take up about 36 of the former and about 32 of the latter. Consequently, if a boiling solution saturated with saltpetre and chloride of sodium be cooled to 70°, it will deposit about 208 parts of the former to about 3·6 of the latter.

All, therefore, that has to be done in refining saltpetre is to make a concentrated solution of this grough material at a high temperature, to run the solution into flat troughs, to keep it in constant agitation as it cools down, and then to remove from it the saltpetre as it crystallizes out of the mother liquor.

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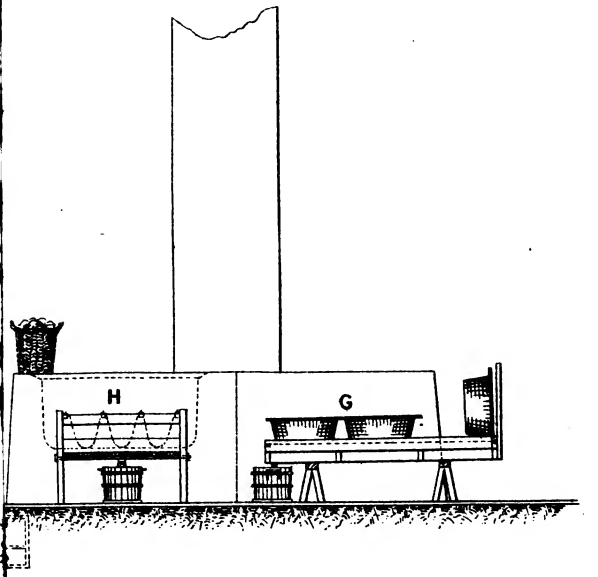
(face p. 12.)

Plate 1.

ALTPETRE,



ner.

H. Filter.

Vincent Brooks, Day & Son, lith.

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The following is a list of the fixtures and apparatus required for carrying on the business of a saltpetre refinery capable of preparing 50 cwts. of refined saltpetre *per diem*.

List of Fixtures and Apparatus.

Bags, filtering	-	-	24
Barrels	-	-	60
Barrows, coal	-	-	3
„ hand	-	-	4
Baskets, 1½ bushel	-	-	4
Bins, wood	-	-	3
Bottoms, false (for coppers)			3
Bowls, copper	-	-	3
Cisterns, wood	-	-	2
„ „ lined lead	-	-	1
„ copper (coolers)	-	-	4
Coppers, large	-	-	2
„ middling	-	-	2
„ small	-	-	1
Covers, wood	-	-	50
Ladles	-	-	2
Machine, weighing	-	-	1
Pans, copper bearing	-	-	1
„ „ crystallizing	-	-	100
„ „ pouring	-	-	4
Pipes, copper	-	-	3
Pokers, stokehole	-	-	2
Pots, iron evaporating	-	-	2
„ tin water	-	-	4
Platform, wood	-	-	1
Pumps, copper	-	-	4
„ lead	-	-	1
Racks, wood	-	-	4
Rakes, stokehole	-	-	2
„ wood	-	-	3
Scrapers, copper mill	-	-	3
„ iron	-	-	5
Shovels, copper	-	-	7
„ iron	-	-	9
„ stokehole	-	-	2
Spuds, iron	-	-	4
Skimmers, canvas	-	-	1
Stands, filtering	-	-	6
Stills, wood	-	-	12
Stirrers „	-	-	5
Stools „	-	-	20
Tressels, sorts	-	-	8
Troughs, wood	-	-	7
Trucks	-	-	8
Tubs, liquor	-	-	20
Tubing	-	-	ft. 18
Weights, iron set	-	-	1

Description of the Refining Process.

1. *Solution.*—About two tons of grouph saltpetre is placed in a large open copper pan (capable of holding about 500 gallons of water), and about 270 gallons of water are added to it. This is generally done over night, and the fires are lighted under the copper at 5 a.m. the following morning. Over the bottom of each pan is placed a false bottom of iron, perforated with holes of an inch in diameter, to allow the sand and insoluble impurities to fall to the bottom. In about two hours time the whole of the saltpetre will be found to be dissolved and the solution boiling, and the specific gravity of the solution being about 1·49, it reaches the temperature of 230° Fahr. The false bottoms are pulled out just before the solution begins to boil, and the scum containing the greater part of the organic impurities is removed from the surface. The solution is allowed to boil for about half an hour longer, until no more scum rises to the surface; the copper is then filled up with cold water, and the solution again boiled briskly for a few minutes, after which it is allowed to cool down to become of a proper temperature for being pumped into the coolers.

The illustration gives a general idea of the apparatus used in refining. (Plate I.)

2. *Filtering.*—When the temperature of the solution has fallen to about 220° Fahr. with a specific gravity of about 1·53 it is ready for pumping into the filters. The filtering process is almost always used when refining saltpetre for gunpowder-making, but is sometimes omitted in commerce when refining for other purposes. In the latter case the solution is made of extra strength and consequently denser, and the cooler being placed below the level of the coppers, the solution is run directly into it through a pipe, the orifice of which in the copper is placed at a certain height above the bottom to prevent the sediment running out with the clear liquor. But filtering affords a much more certain plan of obtaining a clear liquor for crystallization, and presents little difficulty and causes very little loss of time. When the solution is judged to be at a proper temperature for the process, a common

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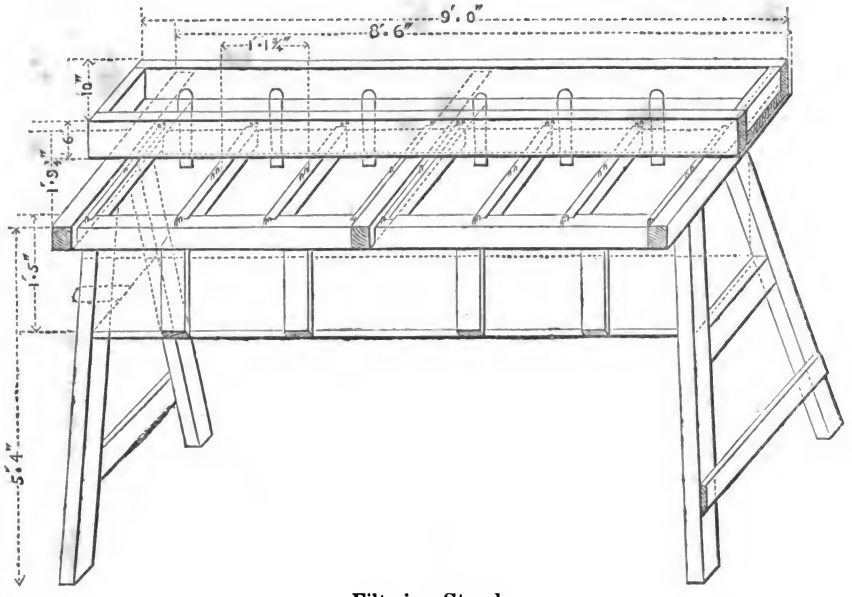
hand-pump is lowered into the copper, and the solution is pumped into a wooden trough leading to another larger one termed the "supply trough," furnished with six holes in the bottom beneath which the filtering bags are suspended. Wooden plugs are provided for these holes in the bottom of the "supply trough," so that if the bags become clogged the flow of solution may be stopped till they are replaced by clean ones.



Filtering Stand.

The bags (known as "refining bags") are made of "dowlas." They are suspended on iron hooks underneath the holes in the supply trough. They are always rinsed with hot water before the filtering commences, and require occasionally a little poured over them to prevent the formation of crystals during the process, which would clog the canvas and prevent the solution running. Occasionally a solution is found to contain so much organic impurity that it will not run through the filters. In this case a little glue, about 1 lb. to 2 tons of saltpetre, is added to the solution in the copper, which has the effect of throwing up a great part of the impurity as a scum, which can be removed before the liquor is pumped out. The filtering of a copper-full of liquor of the strength described under the head of *solution* takes about three-quarters of an hour. As soon as it is all removed from the copper, the pumps, which are suspended overhead on a small pulley, are pulled up, and the coppers, if necessary, cleaned out. The sediment, consisting principally of sand in the proportion of about ¼ per cent. of the grough, is washed, and the washing reserved for evaporation. A wooden trough placed directly underneath the filtering bags receives the solution as it runs from them, and conducts it directly into the cooler. When all the solution is filtered the bags are rinsed with hot water into the evaporating pots, are then washed in hot water, then in cold, and finally hung up to dry.

3. *Crystallization.*—The cooler or crystallizing cistern is a large shallow flat trough of sheet copper, being about 12 feet long, 7 feet wide, and 1 foot deep. By the time the solution runs into it the temperature will have fallen to between 190° and 180° Fahr. As the

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temperature continues to fall the excess of saltpetre crystallizes out, leaving of course a considerable quantity still in solution, and along with it the chemical impurities of the grough salt, the chlorides and sulphates. If the solution were left to crystallize without agitation the salt would be deposited in the form of large crystals, each of which would enclose a small quantity of this impure mother liquor. To prevent this the liquor in the coolers must be kept in constant agitation, to cause it to deposit the salt in the form of "flour," or minute crystals. This is effected by a workman who, for the first hour or so, until the temperature of the liquor falls to about 90°, keeps it constantly stirred by means of a large wooden hoe, with which also the "flour" is drawn to the side of the cooler, to be shovelled out with a copper shovel. As it is removed it is first thrown on to an inclined board or "drainer," to allow the excess of liquor to run back into the cooler. It remains on the drainer for some minutes, after which it is transferred to the washing vat. When the liquor falls in temperature to about 90° the agitation is discontinued, because the crystals are deposited much more slowly, so that the cost of labour would be considerably increased. The crystals which are deposited at a temperature below this also contain a much larger quantity of mother liquor. About three-quarters of the entire quantity of saltpetre is removed from the solution if the agitation be stopped at 90°. The crystallizing process may be very materially hastened by artificial cooling. In some refineries where a good fall of water can be obtained a stream of cold water is made to run under the bottom of the cooler. This reduces its temperature very rapidly, and causes the "flour" to be deposited with less loss of time.

The mother liquor is left to cool down after the proper amount of "flour" has been removed from it. As soon as its temperature approaches that of the atmosphere large crystals are deposited on the cooler. The liquor (still of course a saturated solution containing all the original soluble impurities) is run off and reserved for subsequent evaporation. The crystals are scraped off and transferred to the refining copper with the next charge of grough. The following is an analysis of a sample of the salts left in solution in the liquor :—

Saltpetre - - - - -	77·40
Chl. sodium - - - -	18·51
Sulphate of soda - - - -	3·39
	99·30

which should be compared with the analysis of the grough salt.

4. *Washing, testing, and drying for store.*—The washing vat to which the saltpetre "flour" is transferred is of wood, about 6 feet long, 4 wide, and 3½ deep. It is provided with a false bottom pierced with small holes, underneath which is a plug hole which can be closed or opened as required. In this vat the saltpetre receives three washings, the first being given at once, as soon as it is raked from the strainers into the vat, to remove the excess of mother liquor still adhering to it. About 70 gallons of water are run through the vat, and escaping from the plug hole underneath the false bottom, are conducted into an underground tank. The second washing is done by covering the crystals with water and allowing it to stand for half an hour (the plug being put in), and then allowing it to run off into a second underground tank. The crystals are allowed to drain for half an hour after this washing. The third washing is given by running about 100 gallons by water through the crystals as in the first washing, the plug holes remaining open. The water from the third washing runs into the tank which receives the second, the contents of which, being comparatively free of impurities,

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are used in the refining coppers. The water from the first washing is only used in the evaporating pots.

It is, of course, most important that the purest water should be used for these washings. Distilled water should, if possible, be alone employed. At Waltham Abbey the water used is from an artesian well, and is remarkably free from mineral impurities. The washings as they run off are saturated solutions of saltpetre; but they take up in passing through the salt any traces of chlorides remaining in it.

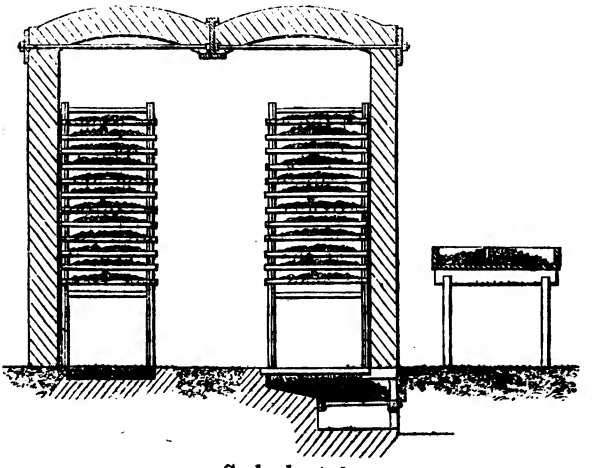
Supposing all the forgoing operations to have been properly carried on the saltpetre will be found to be perfectly pure. Should it be deemed necessary to test it for impurities, it should be subjected to the following. A solution should be tested:—

1. With blue and red litmus paper for the presence of an acid or alkali.
2. With a solution of nitrate of silver for the presence of chlorides, which would throw down the insoluble chloride of silver.
3. With a solution of chloride of barium for the presence of sulphates, which would give the insoluble sulphate of baryta.
4. With a little oxalate of ammonia for lime, which would give oxalate of lime.

In the ordinary practice of a refinery, the second test, viz., that for chlorides, more especially the chloride of sodium, is the only one ever made use of.

The saltpetre is transferred to the store bins, generally the day after it is refined. In removing it from the washing vats about 6 inches deep at the bottom is left, as it contains a great deal of water. After remaining in the bins for three or four days it will be found to contain from 3 to 5 per cent. moisture, according to the season. It remains in the bins till required for use in the mixing house, the saltpetre used for powder-making being always used moist.

Should a supply of refined saltpetre be required for storage or transport, the salt is generally dried before being placed in barrels. This is done in a hot chamber, which does not require any particular description, being merely a small room with a stone floor, underneath which runs a flue, and provided with racks inside, on which are placed the flat copper trays containing the saltpetre.



Scale about $\frac{1}{6}$.

The hot chamber or store is capable of containing about $2\frac{1}{2}$ tons of saltpetre, and the temperature is gradually raised to about 220° Fahr., which dries it completely in from four to six hours time. The salt is cooled

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in a flat tray placed outside the store before being barrelled up for store ; 84 lbs. of the dried refined salt is generally placed in each whole barrel.

Treatment of the Mother-liquor Washings, refuse Salts, &c.—The process of refining being finished, there remains on the refiner's hands a quantity of impure liquors containing a large amount of saltpetre in solution, which requires to be boiled down and crystallized. There is—

(1.) The mother liquor from the crystallizing cisterns out of which the excess of pure saltpetre has been removed in the form of "flour;" a saturated solution of saltpetre containing all the original soluble impurities.

(2.) The mother liquor from the small copper crystallizing pans, to be afterwards described, also a saturated solution.

(3.) The first washing of the refined saltpetre.

(4.) Any of the second and third washings which may not be required for the refining pot; and,

(5.) The rinsings of the filtering bags used in refining, the whole amounting to about 600 gallons per diem when refining two coppers a day.

The apparatus for evaporating is similar to that for refining, but the coppers are not so deep. There is a large open copper pan or boiler, and a wooden trough provided with filtering bags. For this purpose, however, the bags known as "extracting bags" are made of coarser material than those used in refining.

It is important that the object and meaning of the evaporating process should be clearly understood. If it was merely intended to drive off the water from the salts held in solution, in order to obtain them for future refining with the grough saltpetre, it is obvious that the impurities present instead of being eliminated *would accumulate* and defeat the refiner's object. The process is intended to get rid of the greater part of the soluble impurities—the chlorides and sulphates—and depends, as does the refining process just described, for its success on the high solubility of saltpetre in boiling water. This property of the salt enables the refiner to remove the greater part of the impurities by a simple boiling, for as the water evaporates the saltpetre still remains held in solution, while the other salts, being much less soluble at that temperature, are separated and fall to the bottom of the copper.

The process is conducted as follows :—The solution, amounting to about 300 gallons in each pot, is boiled till it is reduced to about one quarter its original bulk. If the boiling commences the first thing in the morning, part of the chlorides and sulphates will be found to have formed on the bottom of the copper about 11 a.m., after which an iron spud must be frequently used to prevent the salts caking on the bottom.

The following is an analysis of a sample of these salts :—

Saltpetre -	-	52·96 per cent.
Chloride of sodium	-	17·96 „
Sulphate of soda -	-	24·56 „

About 2 p.m. the solution will be sufficiently reduced, and is then transferred to the filters with ladles, leaving the residue in the coppers. From the filters it runs direct into the crystallizing pans (small pans of copper holding about 17 gallons each). In these the solution is allowed to crystallize, the mother liquor, still saturated with the saltpetre and the impure salts when cold, being reserved for a future day's evaporation, and the crystals being reserved for refining with a fresh supply of grough. The salts left at the bottom of the evaporating pots are treated as follows :—

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The main bulk of them consists of the chlorides of sodium and potassium, the remainder being made up of the sulphates of soda and potash, with a trace of sulphate of lime.

Hot water is first poured over them, and the whole stirred up together, and the mixture filtered through baskets lined with saltpetre bags into the crystallizing pans. The hot water of course dissolves out a much greater proportion of saltpetre than it does of the other salts. The contents of the baskets are allowed to accumulate for a second boiling in a saturated solution of the impure salts which dissolves out nearly all the saltpetre remaining. The liquor is again filtered through baskets lined with saltpetre bags into the crystallizing pans, and the salts left in the basket are transferred to the waste salt store for subsequent sale. The following are analyses of four specimens of waste salts reserved for sale :—

—	1	2	3	4
Sulphate of potash (per cent.)	4·62	5·35	6·52	4·42
Chl. of potassium („)	30·43	34·80	44·50	70·83
„ sodium („)	40·54	74·20	25·87	5·19
Insol. residue („)	·25	·56	·36	1·44

The reader will not fail to remark the presence of a potassium salt in large quantity in the residue after refining, and it will doubtless occur to him that it might be advantageously converted into the nitrate. There is, of course, no difficulty in the matter, the question is one of expediency only. It has been tried with perfect success at Waltham Abbey ; but as long as a good price (the last was 20*s.* per ton) can be obtained for the refuse salts, there is no advantage in carrying on the conversion. The process is as follows :—

The mother liquor from the evaporating pots saturated with chlorides is the only liquor operated on. To each evaporating pot full of this 1 cwt. of nitrate of soda is added, and the liquor reduced by boiling to about one quarter of its original bulk. The chemical reaction is this :

$$K\,Cl + NaO\,NO_5 = KO\,NO_5 + Na\,Cl.$$

Just as in the evaporating process formerly described, the excess of chloride is deposited at the bottom of the copper, as the bulk of the liquor becomes reduced, and will amount to about 5 cwt. when the solution is reduced three fourths. The liquor is then ladled into the filters, and run into the crystallizing pans, where it deposits crystals of impure saltpetre. The residue left in the copper is kept until about 1 ton has accumulated, when the whole is broken up and gradually stirred into 100 gallons of boiling water in one of the evaporating pots. This will leave undissolved about 10 cwt. of salt, principally chloride of sodium, which is from time to time removed, and after being allowed to drain in baskets lined with saltpetre bags transferred to the waste salt store. To the solution remaining in the pot 3 cwt. of nitrate of soda is added, the solution boiled down and filtered as before, and finally allowed to crystallize. Each ton of the original residuum would yield in this way about 4½ cwt. of saltpetre. The residue left in the evaporating pot at the completion of the second process is reserved to be boiled up with the next quantity operated on.

Bag-washing and scraping : Extraction of Saltpetre from damaged Powder.—The processes of bag-washing and extraction of saltpetre from damaged powder and powder sweepings still remain to be described

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as forming part of the ordinary routine of duties in a refinery of saltpetre.

Saltpetre bags from their coarse texture are found to retain a considerable quantity of the salt when emptied. The dampness to which they are subjected in storage and transport causes a firm adherence of a layer of crystals, and moreover saturates the fibre of the bags with saltpetre. To obtain all the salt, the bags therefore require to be cut open and firmly scraped with a blunt knife, then brushed with a very stiff broom or brush, and finally soaked and boiled. It is found to be a better plan to operate on the whole of the year's supply of bags at once than to carry on the process from time to time. Fine weather is necessary for drying the bags before being packed for sale. The operations hardly require description. To enable the scraping to be thoroughly done the bags are cut open and hung on two iron hooks against a wall. When about 500 are scraped they are transferred in lots of 100 each to the copper with about 350 gallons of water, and boiled for half an hour. They are then drawn out of the pot and placed on a rack over it, to allow the excess of liquor to drain back into it, and are afterwards thrown into a tank of cold water for another half hour. On being removed from that they are allowed to drain into it for a short time, then washed one by one in the river with an iron hook, and finally hung up to dry on the frame erected for the purpose. If the weather is fine they will be sufficiently dried in three days time, but they require to be turned on the second day. The cold water in the tank is reserved for boiling the bags the following day. The liquor in the copper is treated exactly as the mother liquor in refining, being boiled down till it is of the proper density for crystallization, throwing out during the boiling the greater part of the soluble impurities contained in it. About 16,000 bags are scraped and boiled at the Royal Gunpowder Factory annually, generally during the months of June and July.

The extraction of saltpetre from powder sweepings, a considerable quantity of which accumulates in the course of manufacture, and from powder which may have been accidentally wetted or damaged by long storage in damp magazines, is also an annual operation which takes place at Waltham Abbey. The number of barrels of sweepings per annum is generally about 160. Copper pans are used for storing the sweepings in, and any damaged powder which may be sent to the factory from time to time is placed in pans also. As a precaution the contents of each pan is carefully and thoroughly wetted. The store should be inspected from time to time to see that the powder is not allowed to become dry by evaporation.

The operation of extracting is performed as follows :—About 240 gallons of water are pumped into a copper of 400 gallons capacity, and brought nearly to the boiling point. Pure water would be used for the first day's operation, but afterwards the liquors obtained in filtering the previous day's work. About 900 lbs. of the damaged powder are then thrown in, care being exercised that it is thoroughly wetted throughout before being brought into the extracting house. The mixture is stirred and boiled for three quarters of an hour. The stirring must be kept up carefully to prevent the powder caking at the bottom, which would result in a subsequent sudden generation of steam throwing the boiling liquid out of the pot, after which the fire is damped and the solution ladled into filters of coarse sheeting. From the first series of filters the solution passes to a second row made of dowlas, the same previously described as "refining bags," through which it passes clear into a tank. From the tank it is subsequently pumped into the evapo-

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rating pots and boiled down. The saltpetre being of course pure the boiling in this instance is merely to drive off a certain quantity of water. When sufficiently reduced it is again filtered through dowlas, as in the original process of refining, and crystallized in the small copper crystallizing pans. The crystals obtained are used as grough saltpetre; the mother liquor, still a saturated solution, is reserved for a second boiling down in the evaporating pots.

The carbon and sulphur in the first two series of filters is allowed to drain for a couple of hours. The whole, including the filtering bags, is then thrown into a second pot of 300 gallons capacity with 200 gallons of water, which is well stirred, and the bags being removed, the liquid heated nearly to the boiling point. The filtering bags are subsequently washed in the river. The solution is ladled out as before and filtered through "extracting bags," and is reserved for boiling up a second supply of the damaged powder. The carbon and sulphur, after again draining for two hours, is thrown on to the waste heap, being of no value.

The whole process of extraction is dirty and troublesome, and the expediency of carrying it on to any great extent depends on the price of saltpetre at the time, and the price which can be obtained in the market for damaged powder. Powder sweepings should of course always be extracted, as they are liable to contain particles of foreign substances; but provided powder be merely old and dusty it may still be well adapted for blasting operations, and may fetch a good price. Of late years it has been customary for the government contractors to supply new powder in exchange for the condemned and unserviceable, at various rates of exchange. They received at first 320 barrels of condemned powder for 134 of new R.L.G. The rate has since risen.

About 94 per cent. of the saltpetre contained in powder can always be obtained by extraction, against the value of which must be set off the cost of the men's wages employed in the process, the amount of fuel expended, &c.

Annual Loss in refining Saltpetre.—A certain amount of loss of material must always be expected in refining saltpetre on a large scale. This occurs in various unavoidable ways. A small proportion is always lost with the refuse salts, which cannot be made to yield all the saltpetre contained in them, but this constitutes a small amount of the total loss. Taking the average of several years observations at the Royal Gunpowder Factory, and comparing the result with those obtained in the trade refineries, it may safely be asserted that a loss of at least 2 per cwt. may be expected, independent of the actual amount of refraction. Thus the yield of saltpetre at 5 per cwt. refraction will be found after refining to be about 105 per cwt. of the original weight of grough salt.

General routine of Duties in the Saltpetre Refinery.—The general daily routine of duties in the refinery at Waltham Abbey is as follows:—

The fires being lighted by the stoker at an early hour, the foreman and labourers on coming to work pump into the cistern for the supply of the refinery about 800 gallons of water from the artesian well, for washing the refined saltpetre later in the day.

2. They pump into the evaporating pots the first and second washings of the previous day, and run out, by means of the plug holes, the mother liquor from the crystallizing cisterns, which has a specific gravity of about 1·13.

3. They pour off the mother liquor from the crystallizing pans, and set the pans on edge to drain. The pans are allowed to drain for two days.

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4. They scrape out the crystals of saltpetre from the large crystallizing cisterns, and place the salt in pans to drain for two days.

5. They take out the finished refined saltpetre from the washing cisterns, leaving the lower six inches, which contains much moisture, at the bottom, and place it in the store bins.

The foregoing duties are generally got over before breakfast time; after which—

6. They cut open a fresh supply of bags of saltpetre, placing the salt in tubs in quantities of 112 lbs., ready for the refining copper.

7. They then arrange the three filtering frames and the troughs for conveying the solution from the refining copper to the crystallizing cisterns.

8. After the solution is filtered a man is required at each crystallizing cistern for an hour or so to keep the liquor in constant agitation, to ensure the deposition of the saltpetre in the form of flour.

9. Later in the day, after the whole of the sediment, &c., has been removed from the refining copper, they pump about 280 gallons of the second and third washings into them.

10. About 2 p.m. the liquor in the evaporating pots will be ready for ladling into the filters. The filtering will take about ¾ hour's time for each pot.

11. Finally, the refining coppers are charged with saltpetre for the next day's work. In each pot (if more than one is being used daily) is placed about 11 cwt. of drained crystals from the crystallizing cisterns and pans, with about 24½ cwt. of grough salt. The 280 gallons of the second and third washings, previously pumped in, contain about 4½ cwt. more in solution, making a total in each pot of about 40 cwt.

12. Cleaning and mopping-up complete the day's labour.

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CHAPTER III.

THE SULPHUR REFINERY.

CONTENTS.—The sulphur used.—Where obtained.—Its value as an ingredient of gunpowder.—The two forms, electro-negative or soluble, and the electro-positive or insoluble sulphur, the former alone used in powder making.—Reason for this.—Description of the refining process as carried on at Waltham Abbey: the melting pot; the receiving pot; the subliming dome.—Distillation and sublimation, how conducted.—Explosions in refining, how caused.—Ladling out and solidifying the sulphur.—Loss in refining sulphur.—Testing refined sulphur.—Value of sulphur as an ingredient of powder.

THE sulphur used at Waltham Abbey is imported from Sicily. The finest quality, known as "Licara firsts," is alone employed. As imported the sulphur contains from 3 to 4 per cent. of earthy impurities, having already undergone a rough purification by distillation before it comes into the merchant's hands. It is finally and carefully purified at the Royal Gunpowder Factory by a second distillation.

The value of sulphur as an ingredient of gunpowder is due to the low temperature at which it inflames. It melts at a comparatively low temperature (239° F.), and inflames at about 560°. The substance exists in several distinct conditions or forms, two of which require special notice when speaking of it as an ingredient of gunpowder, viz., the soluble or electro-negative form, and the insoluble or electro-positive. Distilled sulphur consists almost entirely of the former, sublimed sulphur contains a large proportion of the latter. Distilled sulphur, as used in the manufacture of gunpowder, consists of masses of clear yellow crystals in the form of rhombic octahedra, and is readily soluble in bi-sulphide of carbon. Sublimed sulphur (known as "flowers-of-sulphur") is a pale yellow powder, composed of minute particles which do not present a crystalline structure, but which are merely minute granules consisting of insoluble sulphur, inclosing a small portion of the soluble variety. This latter form of sulphur is to a great extent insoluble in the bi-sulphide.

It is generally stated that the reason flowers-of-sulphur cannot be used for powder-making is because having been deposited in a chamber containing a considerable amount of sulphurous and sulphuric acid, they are always found to present a decided acid reaction which would be injurious in the finished powder; but Professor Bloxam points out that it is much more likely that the properties of the electro-positive or insoluble sulphur, of which they are in a great measure composed, may exercise an injurious effect on the action of gunpowder. This, however, is a point which still requires to be decided by experiment.

The process of distillation at Waltham Abbey is very simple. The following figures (Plates 2 to 6) show—

The iron pot or retort in which the process is carried on: (1) section through water jacket; (2) section through pipe to subliming dome; (3) ground plan; (4) a longitudinal section of the sulphur refinery, showing the setting of the pot and the communication with the subliming dome; (5) a transverse section of ditto, showing the communication between the pot and the receiving pot.

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Plate 2.

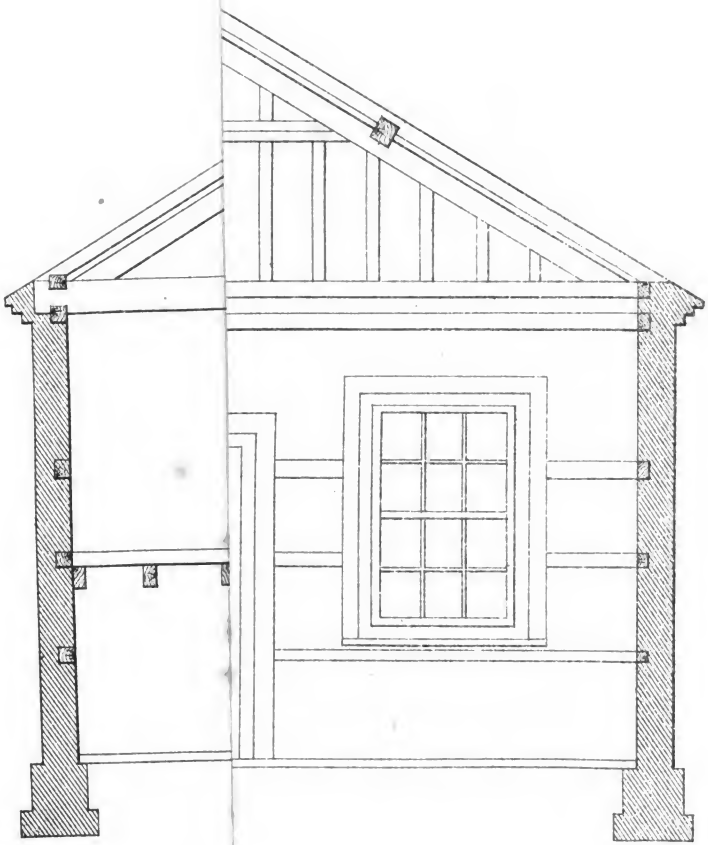

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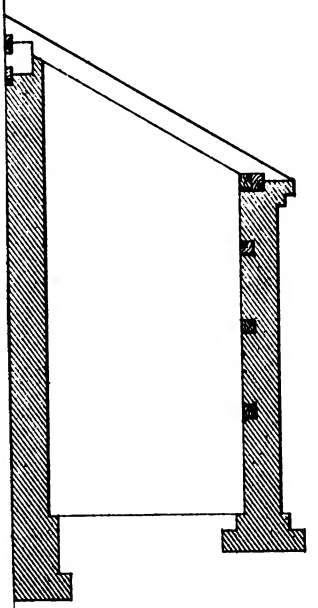
Plate 3.



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The apparatus employed consists of a large pot of cast iron, about 1 foot 8 inches deep, 3 feet 4½ inches in diameter at the mouth, and about 2 feet 2 inches at bottom. The metal of the pot is very thick, being about 2½ in. thick at the edge, and nearly 6 in. at bottom. Round the top edge is shrunk a strong ring or tire of wrought iron to prevent splitting by expansion. This pot is set in brickwork, as shown in the cut. On the top of it is fitted a large dome-shaped cover, also of cast iron, secured to the pot by three wrought-iron tie-rods, which are secured by screw bolts to a wrought-iron ring passing round the neck of the cover.

At the top of the cover is a circular opening, 1 foot 6⅜ inches in diameter at top, and 1 foot 3¾ inches diameter at bottom. This is fitted with a heavy cast-iron lid, the weight of which is sufficient to keep it in its place during the refining process. In this lid is a 4-inch iron plug-hole with a considerable amount of taper through which the pot is charged. The cast-iron plug which closes it fits sufficiently tightly to prevent escape of sulphur-vapour, particularly if a little sand be thrown over it; but at the same time it acts as a safety valve, being lifted out if an unusual pressure of vapour is exerted inside the pot.

From the dome-shaped cover two pipes proceed at right angles to each other, one to the subliming dome, the other to the distilling tank or receiving pot. The first pipe is 1 ft. 3 in. in diameter, and is furnished with a throttle-valve which can be closed or opened by a handle from without, so as to shut off or open the communication between the pot and the dome when required. The other pipe is encased in a water jacket, and can also be closed or opened by means of a conical valve worked by a screw. When distilling, a constant flow of water is maintained through the water jacket from a cistern overhead, which is filled by a force pump in the house. There is an escape-pipe fitted to the water jacket to allow of the escape of water when there is a sudden development of steam caused by the heat of the sulphur-vapour. This pipe leads directly into the receiving pot, as shown in the cut. The receiving pot is merely a large circular vessel of cast iron, 3 ft. 6 in. in diameter, which is set on a frame mounted on small trucks to allow of a slight movement when the pipe which connects it with the melting pot becomes expanded and lengthened by the heat of the sulphur vapour passing through it. There is a large circular opening in the lid through which the melted sulphur can be ladled out when necessary. This opening is closed by an iron lid similar to that of the melting pot, in which is also a small plughole through which the depth of melted sulphur in the receiving pot can be gauged with an iron rod. A small pipe leads from another opening in the lid of the receiving pot into a square wooden chamber lined with lead, to receive any non-condensed vapour, and cause it to deposit its sulphur in the form of "flowers." This chamber is provided with a tall chimney, also of wood, containing a series of steps or traps to catch as much of the "flowers" as possible.

The subliming dome is a large dome-shaped building of brick, 10 feet in diameter at base, and about 12 feet in height. The pipe from the sulphur pot enters it near the top. The chamber is lined with flag stones, and the floor is covered with sheet lead. It is provided with two doors, an inner one of iron, an outer one of wood lined with sheet lead, both close fitting, through which passes a pipe to allow the escape of air. This pipe terminates in a vessel of cold water.

The process of refining may now be described.

In the ordinary course of distilling sulphur for powder-making a small amount must always pass into the subliming dome, as will be explained. Occasionally, however, the apparatus is used for subliming

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alone, should a quantity of flowers-of-sulphur be required for any laboratory purposes. The small amount obtained after a week's work at distilling is found to be so contaminated with acid, from the frequent coolings of the dome, as to be unfit for any purpose. It is therefore collected weekly and placed in the pot with a fresh supply of grough material. Very often the two processes, distilling and subliming, are carried on together, but in this case the temperature of the dome is not allowed to fall, and it is thus found perfectly practicable to obtain both distilled and sublimed sulphur at the same time. But it is better on the whole to carry on the two processes separately.

If distillation alone is to be carried on, about 5½ cwt. of grough sulphur is placed in the pot each morning. An extra hundredweight would be put in if both distillation and subliming are to be carried on together. The fire being lighted, the conical cast-iron plug is left out of the hole in the lid of the pot, the passage into the dome is opened, and that into the receiving pot closed. The heat is maintained for three hours, till the sulphur is of a proper temperature for distillation. The vapour which first rises from the pot is of a pale yellow colour, and as much of it as passes into the dome falls down condensed as flowers-of-sulphur. But at the end of three hours the vapour becomes of a deep reddish brown colour, showing that the temperature of the melted sulphur has reached the proper point. The plug must then be inserted in the lid, the communication to the dome closed, and that leading to the receiving pot opened, allowing the heavy vapour to pass through the pipe surrounded with the water jacket, by means of which a constant circulation of cold water is kept up round it. In this way the sulphur-vapour is condensed, and runs down into the receiving pot as a clear orange liquid resembling treacle in colour and consistency. The person who watches the operation knows by gauging the depth of the melted sulphur in the receiving pot when the greater part of the material has distilled over. He then lowers the fire, opens the communication into the dome, and cuts off that leading to the receiving pot, allowing the remaining sulphur to pass off into the dome as flowers. A low fire is maintained till the whole has been driven off, leaving the earthy residue quite free from it, and consequently loose like coal ashes, so that it may be easily ladled out next morning before recharging the pot.

When both subliming and distillation are carried on at once, the first part of the process would be exactly as described above ; but when the distillation was finished the fire would be maintained for the remainder of the day, but somewhat lower, to drive off the quantity required into the dome. And in this case the subliming process would be carried on for several days, and the pot and dome never suffered to cool down altogether till the required quantity of flowers of sulphur had been obtained.

It is of the greatest consequence that the fires should be carefully regulated in all cases, for if the heat becomes too great, and the temperature of the melted sulphur be allowed to rise to 836°, the vapour disengaged at that temperature is highly explosive when mixed with common air ; and if the plug be driven out by the pressure of the vapour, or if air be drawn into the pot through some leakage in the pipes, an explosion invariably happens.

When the distilled sulphur in the receiving pot has cooled down sufficiently, which it will do in the course of an hour or two, it is ladled by hand into wooden tubs and allowed to solidify. These tubs are constructed of a number of loose staves held together by broad wooden hoops, which can be struck off when the sulphur has " set," allowing the

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Face P 24.

Plate 4.

GROUND PLAN OF SULPHUR REFINING APPARATUS.

A. Melting Pot. B. Pipe with water jacket leading to C.
C. The receiving pot. D. Pipe leading to subliming dome.

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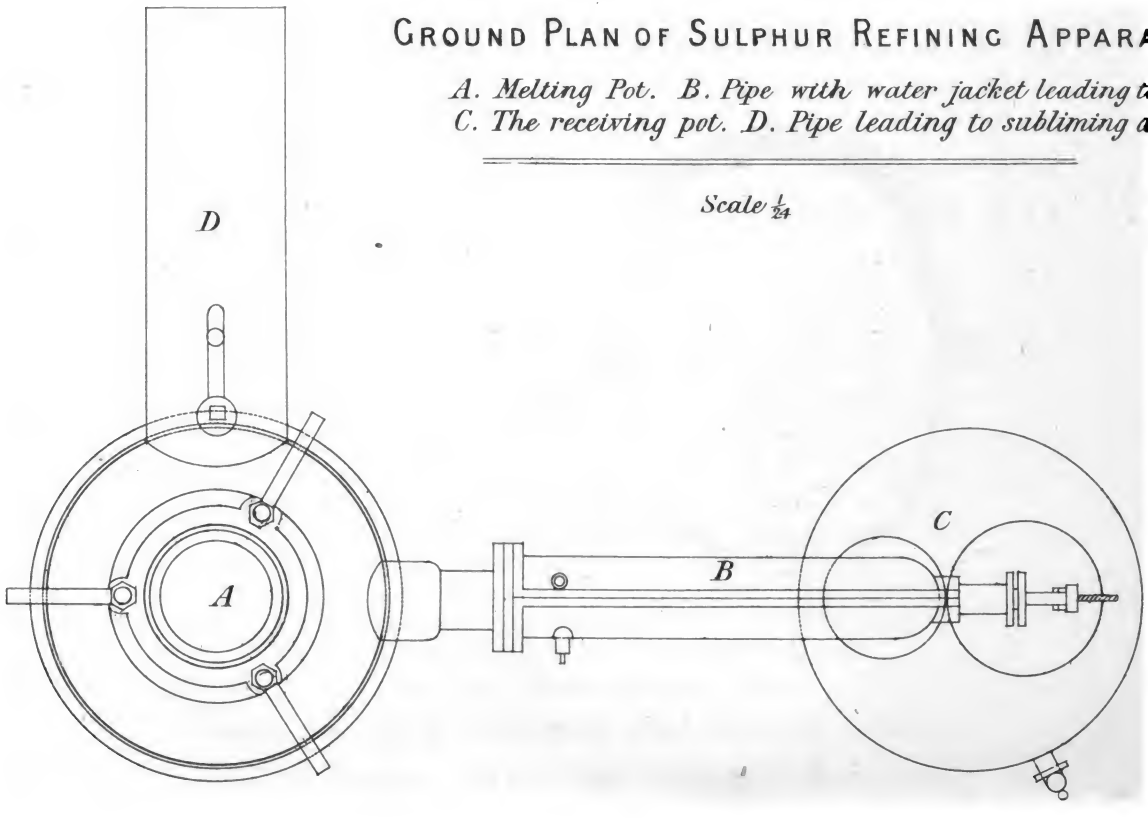

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SULPHUR MELTING POT,

Section through pipe leading to subliming dome.

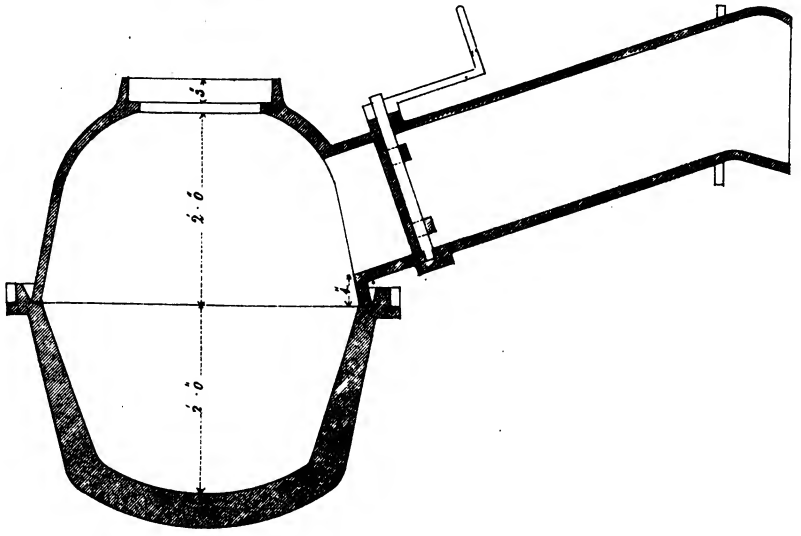

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Plate 6.

SULPHUR REFINING APPARATUS,

Section through pipe leading to receiving pot.

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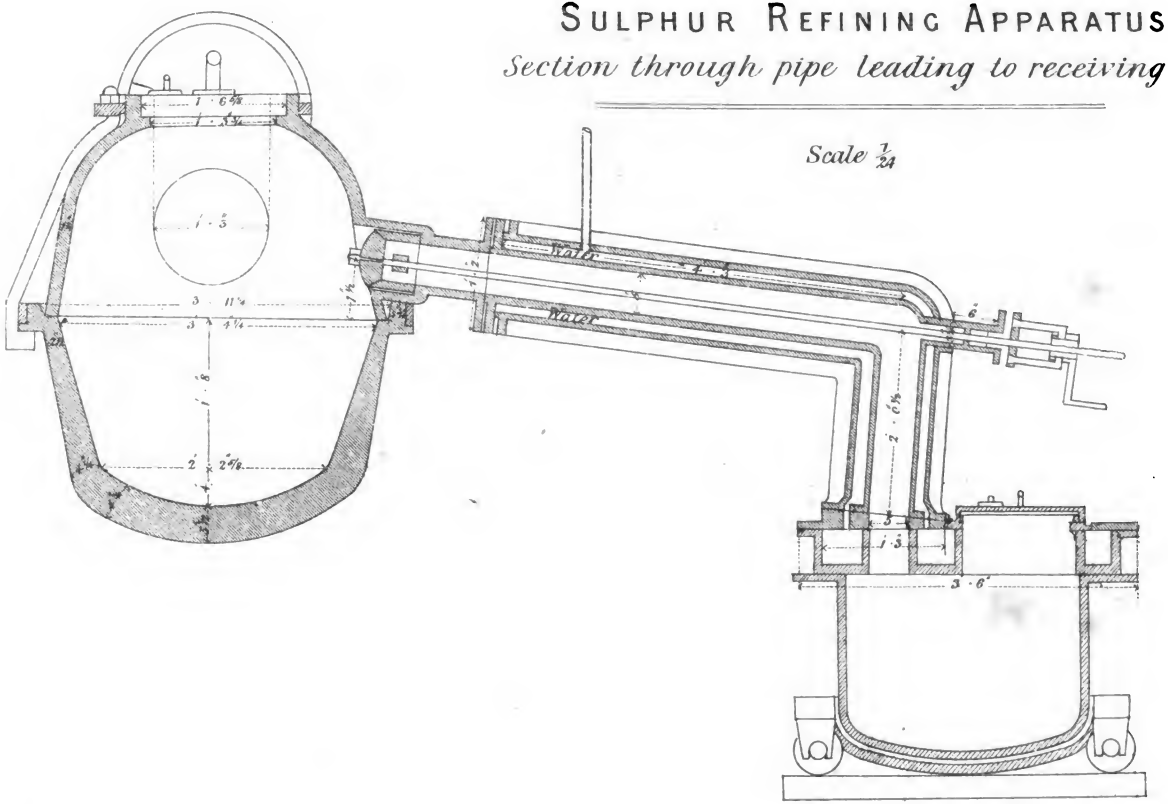

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staves to fall asunder and leave it as a solid cylindrical mass. When not in use these tubs are kept immersed in water, and when required are used damp, to prevent the liquid sulphur adhering to them. One pot, or day's work, yields enough distilled sulphur to fill about 2½ tubs, the weight of the contents of one tub being about 2 cwts. A little of the refined material is left at the bottom of the receiving pot each day, as it is impossible to remove it all with the ladle. This is allowed to remain till the following morning, when it is chipped out and mixed with the grough material. The amount of sublimed sulphur which accumulates in the dome during one week's work of distillation, provided only one potfull is worked off daily, amounts to between 1½ and 1¾ cwts. This, as has been previously said, is found to contain a large amount of acid, it is therefore put back into the melting pot with the grough sulphur. In all cases the dome is opened every Sunday morning and allowed to cool down, that it may be entered and cleaned out on the following morning.

There is practically no loss in refining sulphur. Supposing a certain quantity of grough sulphur be put into the pot, the amount of distilled sulphur, sublimed sulphur, and earthy residue obtained from it when added together will make up the weight originally put into the pot. The process is by no means an expensive one *per se*, but the wear and tear of the plant adds considerably to the cost of refining. The thick cast-iron pots are speedily corroded by the action of the fire outside and the heated sulphur internally, and require to be renewed from time to time, which entails the pulling down and rebuilding of the whole of the brickwork of the fireplaces and flues.

Distilled sulphur immediately after being removed from the tubs is placed within a boarded-off enclosure, to guard against coming in contact with any fragments of grit or sand which might thus enter the powder, and is broken up into large lumps which are sent up to the factory to be ground under a small pair of millstones. After being ground it is reeled through 32-mesh wire-cloth, and is then fit for the mixing-house. It is not generally tested in any way at Waltham Abbey, but its fitness for use as an ingredient of gunpowder may be readily tested :—

1st. By burning a small quantity on porcelain, when the amount of residuum should not exceed ·25 per cent.

2nd. By boiling with water and testing with blue litmus paper, which it should only very feebly redden.

" As an ingredient of gunpowder," says Professor Bloxam, "sulphur is valuable on account of the low temperature (560° F.) at which it inflames, thus facilitating the ignition of the powder. Its oxidation by saltpetre appears also to be attended with the production of a higher temperature than is obtained with charcoal, which would have the effect of accelerating the combustion and of increasing by expansion the volume of gas evolved."

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CHAPTER IV.

CHARCOAL.

CONTENTS.—Woods from which the charcoal used is made.—Alder.—Willow.—"Black dogwood."—Description of each; the "dogwood" really a *Rhamnus*.—Age and size of wood used at Waltham Abbey.—Freeing the wood from bark.—Conditions which affect the keeping qualities of wood.—Stacking of wood.—How long wood should be kept before use.—Charcoal-making as practised at the Royal Gunpowder Factory.—Description of the retorts, flues, cylinders, slips.—Pit charcoal.—Importance of charring wood at a uniform temperature.—Underburnt or underheated charcoal.—Overburnt ditto.—Their effect on powder.—Analyses of charcoals and their ashes.—Reasons of the superiority of the wood now used for charcoal.—Proust and Tomlinson's experiments.—Charcoal tried for small arms.

THE woods from which charcoal is now manufactured for powder-making appear to have been in use from a very early period. Their adoption was no doubt decided empirically, for it is not easy even now to determine why particular woods are better adapted for charcoal for gunpowder than others. It is stated that as early as 1414 King Henry V. ordered 20 pipes of willow charcoal to be prepared for employment in gunpowder making.

The only woods now used in the Royal Gunpowder Factory are the *willow*, the *alder*, and what is popularly known as the *black dogwood*, but which is really the alder buckthorn, or berry-bearing alder (*Rhamnus frangula*). Though various other woods are used by private makers for coarse blasting powder, the three woods named are generally used both at home and abroad for the best gunpowders.

1. *Willow.*—The particular species of willow which finds most favour at Waltham Abbey is the white Dutch (*Salix alba*). This is one of the softest and lightest of English woods. It is of very rapid growth, a section of the wood showing wide and well-marked rings of annual increase. The wood is nearly white and has a tolerably large circular white pith. The more rapidly the wood has been grown the less dense will it be, and the better for powder-making when converted into charcoal. For this reason wood grown in England is generally preferred to that imported from abroad, the foreign wood, both alder and willow, being generally found to be closer in the grain.

2. *Alder.*—The common alder (*Alnus glutinosa*), though supposed to be of exactly equal merit with willow, is considerably harder and denser in texture, and is not of such rapid growth. The colour of the wood is reddish yellow; the pith is triangular in section, resembling in shape the section of a bayonet.

3. The black dogwood (for it has been so long known to powder makers by this name that it may be as well to adhere to it) is, as has been stated, not a dogwood proper (*Cornus*) at all, but the *Rhamnus frangula* (ord. *Rhamnaceæ*), berry-bearing alder, or alder buckthorn.

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It is a handsome underwood of very slow growth, and is found in thickets in many parts of the south of England and in Scotland. The name dogwood has no doubt been applied to it by woodcutters and foresters from its bearing small berries which much resemble the berries of some of the dogwoods proper. The term black dogwood is not known as a botanical name, though the red and white dogwoods are common enough. Several shrubs are called "dogwood" by the common people in various parts of England, such as the wild guelder rose (*Viburnum opulus*), the bird cherry (*Prunus padus*), and the spindle-tree (*Euonymus Europæus*).

Though the *Rhamnus* has been improperly called black dogwood, there is no confusion about the wood itself. It is undoubtedly the *Rhamnus frangula*, and no dogwood, which has found such favour with powder makers both at home and abroad. Though the wood is found in many parts of Great Britain, there are some situations in which it does not seem to thrive. It seems to prefer a poor rocky soil. There are extensive plantations of it at Waltham Abbey, but the main source of supply is the continent, large quantities being occasionally imported from Prussia. The wood is dense and tough, the annual rings being very close together. The pith is circular and reddish in colour, occasionally bright red. This colour is preserved even after the charcoal is burnt.

Small wood of about ten years growth is in all cases preferred for powder making. Alder and willow of this age will be probably four or five inches in diameter, dogwood about one. The two former woods are purchased in pieces of 3 feet long, not less than 1 or more than 4 inches in diameter. The wood must be straight, perfectly sound, and entirely free from bark, and must have been felled during the spring of the current year. The wood is measured for payment by the cord, which is 14 feet long by 3 high by 3 wide, and is always stacked in stacks of 3 cords deep, that is, 9 feet high.

Dogwood is supplied in bundles of long slender rods. The bundles are about 6 feet long, and should be 30 inches in girth at 1 foot from the thick end, and diminish about 4 inches in girth at the upper band. The wood must be perfectly free from bark and clean. This wood is generally purchased by weight, sometimes by bundles. The contracts for its supply describe it as "the wood generally known in England as dogwood."

Great stress is always laid on the cleanness of the wood used for conversion into charcoal at Waltham Abbey. Any traces of bark adhering to it constitute an impurity, and would condemn a supply sent in by a contractor. The specifications imposed on contractors provide that the wood shall be cut in the spring of the year. If this has been done when the sap is rising the bark is easily removed, and the wood is left perfectly clean. But wood cut later in the year, or in winter, is perfectly as good, only in this case the removal of the bark is a much more difficult matter. To separate it the wood must be boiled, or if that be impracticable, the whole of the bark must be shaved off with a knife or spokeshave. Both boiled and shaved wood have been used at Waltham Abbey; but the great objection to both is, that they do not keep so well when stacked as the spring-cut wood, going to decay much faster. As the maintenance of a considerable store of wood is always necessary, any considerations respecting its keeping qualities become very important. All wood is stacked on iron sleepers or on rows of brickwork; the *cord wood*, as alder and willow are comprehensively called, in 3-cord stacks, without any protection from the weather; the dogwood in large stacks of from 30 to 50 tons, covered with straw thatching.

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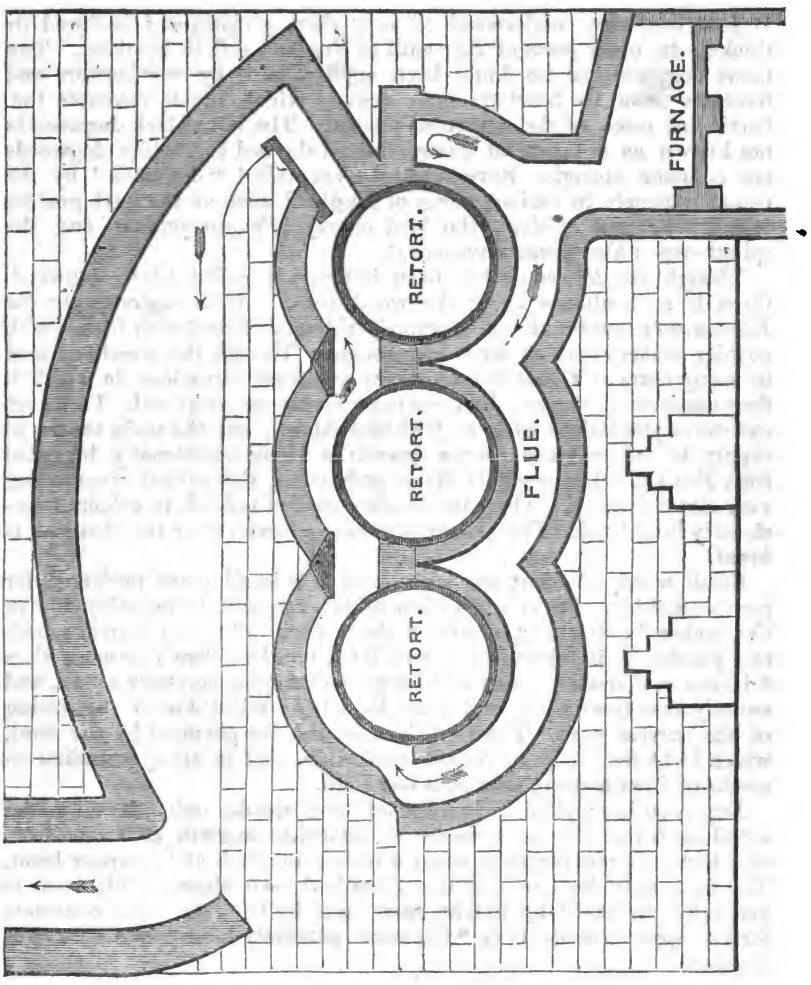

Transverse Section of Retorts.

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There are some minor considerations which affect very seriously the keeping qualities of the alder and willow, and which are therefore worthy of notice. One of these—the method which has been employed to free the wood from bark—has been already noticed. Another, at first sight not of much consequence, should be mentioned, viz., the shape of the ends of the sticks composing a stack. It is found that wood, cut cleanly with axe or bill-hook into a wedge-shaped point, does not absorb so much moisture, and consequently does not decay so soon as wood sawn straight across and left with the rough sawn surface. At Waltham Abbey wood is in excellent preservation after being stacked from seven to eight years. The top layers of the cord wood stacks being exposed to the weather of course decay more rapidly, but the waste caused thereby is so small that it would not be worth while

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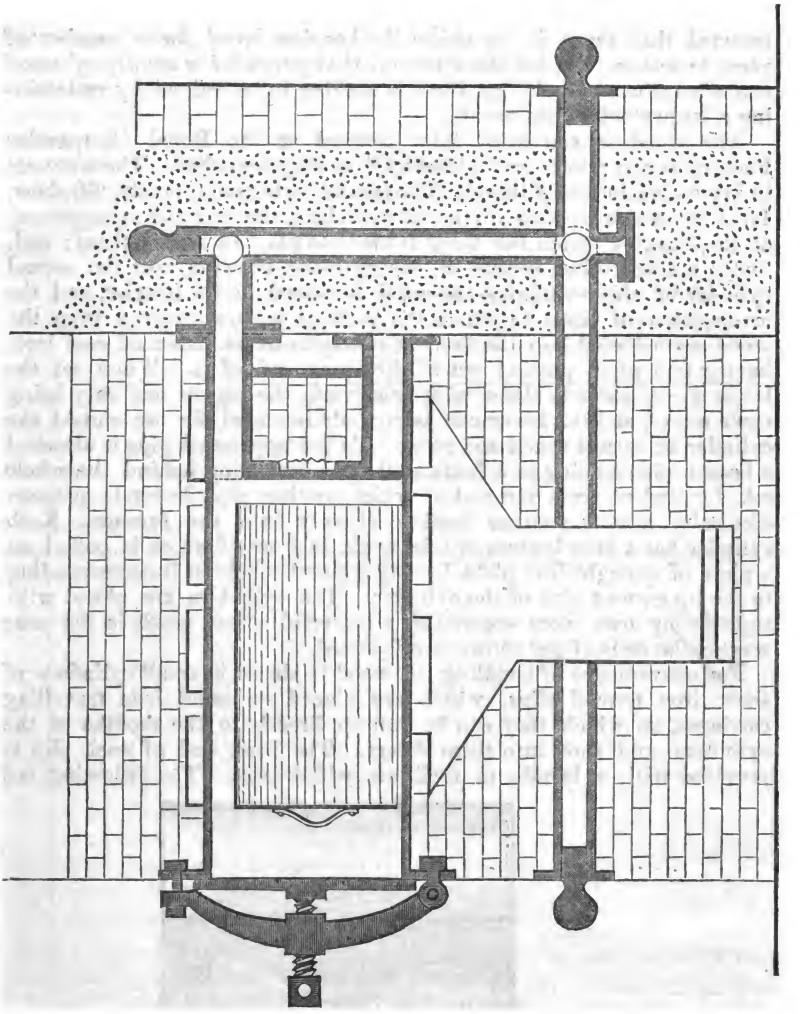

Longitudinal Section of Retort.

Scale about $\frac{1}{28}$.

to incur the great expense of providing cover for them. The stacks of dogwood, when left with proper passages through them for the circulation of air, and well thatched with straw, will last many years without the slightest symptom of decay.

It has been stated that wood is the better for being kept for two or three years before being burnt, but there appears to be no reason whatever for the statement. It is desirable that all the moisture in the wood should be expelled before it is placed in the cylinders to be converted into charcoal. This will be the case after being stacked for a few months in summer. Experiments at Waltham Abbey have proved that the wood parts with all its moisture in a very short time, and ceases to lose weight in two or three months, even under the most unfavourable circumstances. And it may, therefore, be safely

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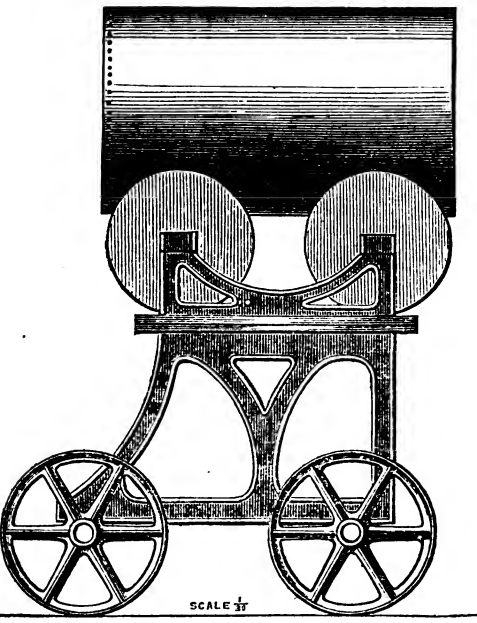
asserted that there is no object in keeping wood for a number of years to season, and, on the contrary, that *provided a supply of wood can always be depended on*, there is nothing to be gained by maintaining a large stock of cut wood.

The wood is converted into charcoal at the Royal Gunpowder Factory in iron retorts, or "cylinders," as they are called. These are set in brickwork in sets of three's. The two following cuts (pp. 28, 29) show, 1st, a transverse section of a set of cylinders, showing the arrangement of the flues, by which the flame is made to play all round them; and, 2ndly, a longitudinal section of one cylinder, showing how the second cylinder or *slip* containing the wood is placed in its interior, and the arrangement of pipes by which the gaseous matter evolved from the wood is conducted into the fire. Each cylinder is made of cast iron, having two pipes passing out of the inner end of it. When set the lower one of these is closed with brickwork, the upper one only being made use of, and the lower one being only intended for use should the cylinder be turned round and reset. To the uppermost pipe is attached a branch pipe leading to a horizontal pipe extending behind the whole set of cylinders, from one end of which another pipe descends perpendicularly, joining another leading directly into the furnace. Each cylinder has a false bottom of brickwork, in front of which is bolted on a piece of wrought-iron plate, having a circular hole in it corresponding to the uppermost pipe of the cylinder. The cylinders are closed with tight-fitting iron doors secured by a powerful screw, much in the same way as the ends of gas retorts are fastened.

For convenience of handling the wood is placed in small cylinders of sheet iron termed *slips*, which are placed on small iron travelling carriages, on which they can be run up directly to the mouths of the cylinders and shot into them direct. The back end of each slip is provided with a handle to facilitate withdrawal. The following cut



shows a slip mounted on the carriage. The slips are a little over three feet in length, so as just to take the cord-wood in easily; but the dog-

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wood being purchased in long bundles requires to be sawn into lengths of three feet before it can be burnt. This is a very troublesome and tedious process if done by hand, as it is difficult to bind the bundles together so closely as to get the saw to work easily. The best plan is to fit up a circular saw for the purpose, if there is any shafting near from which driving power can be obtained.

Provided the cylinders are hot the wood is thoroughly charred in from 2½ to 3½ hours. The plan of conducting the gas and tar from the wood into the fire is found greatly to economize fuel, and to be the readiest means of ascertaining when the charring is properly and thoroughly done. This is shown by the flame which issues from the pipe leading into the fire becoming of a violet tint indicating the formation of carbonic oxide. As soon as this is observed the doors of the cylinders are opened, the slips are hoisted out of them by chain tackle and blocks, and lowered into large iron extinguishers having close-fitting lids, in which they remain for half a day, after which the charcoal is shot into *coolers*—large cylindrical cases of sheet iron fitted with lids—and sent to the charcoal store. Wood yields about 25 per cent. of charcoal. Charcoal is occasionally made in large pits, as may be seen described in various works on chemistry and metallurgy. None has been made in this way at Waltham Abbey for many years. Pit charcoal is preferred for some laboratory compositions, but why it is difficult to say.

It is of the highest importance that the charring of the wood should always be conducted as nearly as possible at the same temperature, for the chemical composition of the charcoal and the temperature at which it will ignite is undoubtedly affected by the temperature at which it has been charred. Charcoal prepared at a low temperature is softer, more inflammable, and contains more gaseous elements than charcoal prepared at a higher heat, and the gunpowders made from these charcoals would be similarly affected. It is hopeless, therefore, to attempt to obtain uniform results in manufacturing powder unless means be taken to ensure uniformity in the preparation of charcoal. At most foreign gunpowder manufactories pyrometers to ascertain the temperature of the cylinders are in use, but at Waltham Abbey the process is entrusted to the experience and careful watching of the foreman.

The fitness of charcoal for gunpowder depends, as has been said, on its chemical composition, which is indicated by its physical qualities. If properly made it should be jet black in colour, its fracture should show a clear, velvet-like surface, and it should be light and sonorous when dropped on a hard surface. Underburnt charcoal, that is, charcoal prepared at a very low temperature, is at once known by its reddish brown colour; overburnt charcoal, by its hardness and density. The former is greatly more inflammable than the latter, charcoal prepared at a temperature of 500° F. being readily ignited at a temperature of 640° F., while charcoal prepared at 1800° F. requires a temperature nearly double the last to inflame it. Underburnt charcoal has found favour for some small-arm powders amongst private makers in this country and in France. It certainly appears to render the powder more inflammable, and consequently quicker, but it has the disadvantage of being more hygroscopic than denser charcoal, and of rendering the powder therefore more liable to suffer damage from damp.

That underburnt charcoal produces a very marked effect on gunpowder there can be no doubt. Recent experiments at Waltham Abbey have proved that if two powders be made identical in all qualities, the one with black charcoal, the other with red or underburnt charcoal, the

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latter will give a higher velocity to the projectile than the former. The following table shows some very interesting results :—

VELOCITIES obtained with R. L. G. POWDER made with different Descriptions of Charcoal. Charge, 1 lb. Shot, 12 lbs.

Date of firing.	Description of Powder.	Charcoal.	Density.	Velocity at 105 Feet.
13th June 1870 -	R. L. G., for India, 26th April 1870	W.A., black -	1·684	1001·8
„ „	„ „ 30th April 1870	„ „ -	1·690	987·0
29th April 1869 -	R. L. G., stoved, 4th Feb. 1869 -	„ „ -	1·68	938·4
23rd March 1869	„ „ 10th „ -	„ „ -	1·69	959·8
„ „	„ „ 12th „ -	„ „ -	1·69	960·3
„ „	„ „ 18th „ -	„ „ -	1·69	942·7
13th June 1870 -	Rework, P. and W. 6th June 1870	P. and W., reddish	1·698	1031·0
„ „	„ „ 7th „	„ „	1·679	1037·5
„ „	„ „ 8th „	„ „	1·687	1041·4
„ „	„ „ 10th „	„ „	1·694	1040·6
4th June 1870 -	„ „ 30th May 1870	„ „	1·681	1030·7
„ „	„ „ 1st June 1870	„ „	1·691	1026·4

Powder made from underburnt charcoal can be readily distinguished, when crushed to fine dust, by its colour.

The charcoals used at the Royal Gunpowder Factory do not vary much in chemical composition or physical qualities.

The following is the result of a recent analysis of some specimens taken at random from a day's work :—

—	Ash.	Carbon.	Hydrogen.	Oxygen, with trace of Nitrogen.
Alder - - -	1·24	87·00	2·97	8·78
Willow - -	2·02	85·82	2·88	9·28
Dogwood - - -	1·71	83·80	3·28	11·21

It will be remarked that dogwood contains a rather larger proportion of gaseous element than the two other woods.

The charcoal from three different specimens of gunpowder (L.G., R.L.G., and pellet) manufactured at Waltham Abbey in different years, when analysed showed a very close agreement in composition.

—	Ash.	Carbon.	Hydrogen.	Oxygen, with trace of Hydrogen.
W.A. L.G. - -	1·61	85·79	2·84	9·76
„ R.L.G. - -	2·02	85·82	2·88	9·28
Pellet - -	2·14	85·80	2·96	9·1

The average densities of the three charcoals are as follows :—

Alder - - - -	1·37
Willow - - - -	1·39
Dogwood - - - -	1·30

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The following is a recent and careful analysis of the ash of each :—

—	Alder.	Willow.	Dogwood.
Silica - - - -	4·66	3·33	17·30
Phos. lime, trace Fe. - -	25·60	27·10	14·53
Lime - - - -	24·90	27·66	31·60
Mg. O. - - - -	2·77	4·25	2·05
Potash - - - -	10·53	11·50	8·20
Soda - - - -	2·21	2·70	3·15
SO_3 - - - -	1·20	2·50	1·22
Chlorine - - -	·15	·25	·54
Carbonic acid - - -	27·82	18·68	20·62
	99·84	97·97	99·21

The woods now used in most gunpowder factories were probably selected centuries ago from actual experiment, being found to make stronger powder than any others. Modern research has shown that there was a good reason for their selection, and that the cause of their superiority over all other woods is probably that their charcoal when burnt along with saltpetre and sulphur yields larger volumes of gas than any others. Proust, who paid special attention to the study of gunpowder, tried a series of experiments with mixtures of saltpetre and equal quantities of the charcoals of various woods, which he burnt together, measuring the quantity of gas evolved. His experiments have been repeated by some English chemists with very interesting results, of which the following is an abstract :—12 grains of the charcoals of the following woods mixed with 60 grains of saltpetre gave the following proportions of gas in cubic inches :—

	Proportions of Gas. Cubic inches.
Dogwood (*Rhamnus frangula*) - - -	80–84
Willow (*Salix alba*) - - - -	76–78
Alder - - - - - -	74–73
Filbert - - - - - -	72
Fir - Chesnut Hazel - - - - - -	66
Elm - - - - - -	62
Oak - - - - -	61–63
Mahogany - - - - -	58
Willow (*overheated*) - - - -	59–66
Oak „ - - - -	54–56

Dogwood, that is, the *Rhamnus*, it will be observed, heads the list, so that there would appear to be a good reason for the opinion which has always been held by powder-makers that dogwood makes the strongest powder ; and, moreover, that an accident in the manufacture of powder made with this charcoal is always more destructive to buildings and machinery than one with any other kind of powder.

Tomlinson endeavoured to ascertain the relative propelling effects of different kinds of charcoal by observing the height to which rockets made-up with the different kinds rose. His results are strikingly

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confirmative of the experiments just described, for he places the relative propelling qualities of dogwood, willow, and alder as follows:—

	Proportion of Nos.
Dogwood - - - -	515–525–550
Willow - - - - -	470–480–490
Alder - - - - -	455–460–470

Various trials of small-arm powders made with a mixture of different charcoals were tried in this country by a committee of officers in 1860. The following mixtures were tried:—

No. 1	- - -	Dogwood.	
2	- - -	$\frac{1}{2}$ dogwood,	$\frac{1}{2}$ small alder.
3	- - -	$\frac{2}{3}$ „	$\frac{1}{3}$ „
4	- - -	$\frac{5}{6}$ „	$\frac{1}{6}$ „

The Committee reported that "willow and alder when properly "selected were suitable for rifle powder, but did not consider a "change advisable, as dogwood is not likely to vary so much in quality in respect to its application to the manufacture of gunpowder, "and as considerable experience has been obtained with dogwood it "would be unwise to make a change."

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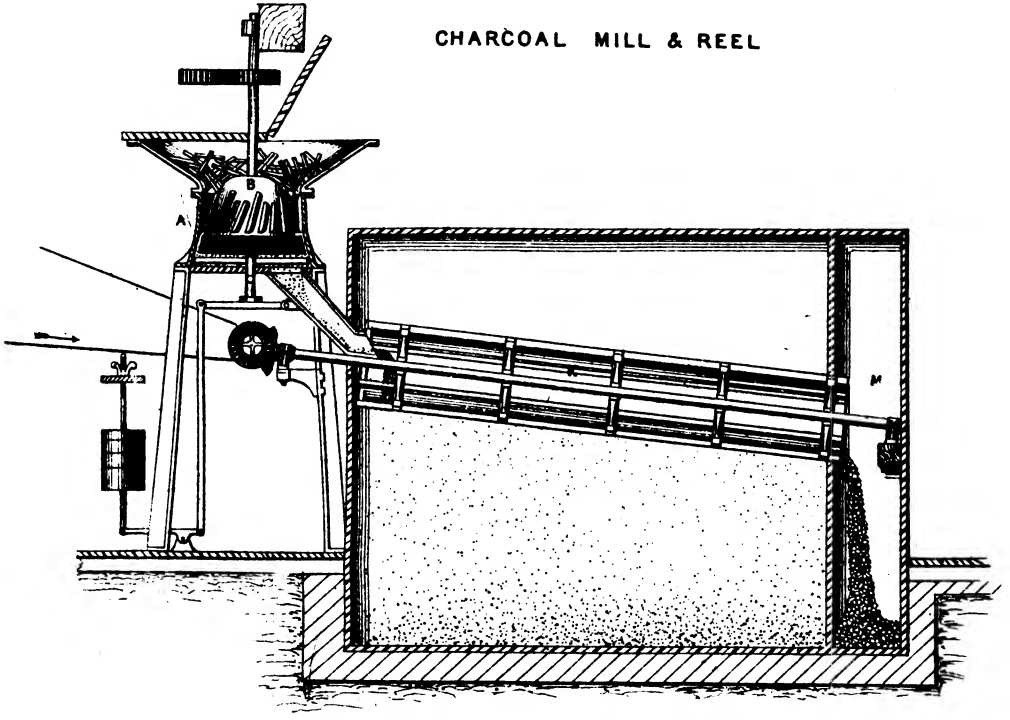
Plate. 7.

CHARCOAL MILL & REEL



Scale $\frac{1}{48}$.

A *Cylinder*.
B *Cone*.

K. *Reel*.

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CHAPTER V.

PREPARING AND MIXING THE INGREDIENTS.

CONTENTS.—Pulverizing the ingredients.—Distinction between mixing and incorporating.—Saltpetre used moist; allowance for moisture.—Table of weights for moist saltpetre.—Grinding and sifting dried saltpetre.—Grinding and sifting sulphur.—The charcoal mill.—Caution as to charcoal grinding.—Weighing the ingredients.—The mixing machine.—Sifting the mixed charge.—Explosiveness of the mixture.—Accidents in mixing houses.

BEFORE the ingredients can be mixed they must be reduced to a powder sufficiently fine for the purpose. It is true that some manufacturers do not pulverize or mix their ingredients at all, but simply weigh out as much of each as is required in lumps and fragments, and throw them on the bed of the incorporating mill. But this clearly involves a loss of time, as the action of the incorporating mill must be at first merely that of grinding and bringing the three ingredients into juxtaposition, before any *incorporation* properly so called can be effected. It is important to bear clearly in mind the meaning of the terms *mixing* and *incorporating* as they are used by gunpowder-makers. Though gunpowder is really only a mixture, very intimate no doubt, of the three ingredients, and not a new chemical substance formed out of them, yet by mixing is understood only the stirring together for a few minutes of the saltpetre, sulphur, and charcoal, to get them properly distributed amongst each other; and by incorporating, the long-continued trituration and grinding which the mixture undergoes under heavy edge runners, by which a mass of the ingredients becomes transformed from a mere mixture of three different substances into gunpowder. A preliminary mixing, such as is employed at Waltham Abbey and most other gunpowder works, *may* be dispensed with; incorporation, whether performed by pestle and mortar, in the stamping mill, or under edge runners, never.

The saltpetre is, as has been previously stated, used moist as it comes from the refinery. It is generally sent up to the mixing house after standing four or five days in the store bins, and when used contains generally from three to five per cent. moisture. For this an allowance must of course be made in weighing each morning, and to enable the mixer to make this accurately, the per-centage of moisture in the quantity sent up each morning, generally amounting to 35 or 40 cwt., when the factory is in full work, is ascertained by the master refiner by drying and fusing a sample, and comparing the weight before and after the operation. A ticket with the proper weight of the saltpetre for the day's charges is given to the master-mixer, who weighs out the saltpetre accordingly. The following table exhibits the weight of moist saltpetre for a 50½ lb.* charge, with moisture from 3 to 6 per cent.

* Though the proportions used in England for gunpowder are 75 saltpetre, 15 charcoal, 10 sulphur, an extra 1 lb. of saltpetre is generally added to the 100 parts to cover loss in manufacture.

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TABLE of WEIGHTS of MOIST SALTPETRE for the 50½ lb. Charge, allowing 76 lbs. to the 101 lbs.

At per Cent. Moisture.	Weight.	At per Cent. Moisture.	Weight.
	lbs. oz.		lbs. oz.
3·0	39 3	4·6	39 14
3·1	39 4	4·7	39 14
3·2	39 5	4·8	39 15
3·3	39 5	4·9	40 0
3·4	39 6	5·0	40 0
3·5	39 6	5·1	40 1
3·6	39 7	5·2	40 2
3·7	39 8	5·3	40 3
3·8	39 9	5·4	40 3
3·9	39 9	5·5	40 4
4·0	39 10	5·6	40 5
4·1	39 10	5·7	40 5
4·2	39 11	5·8	40 6
4·3	39 12	5·9	40 7
4·4	39 12	6·0	40 7
4·5	39 13	—	—

Occasionally dried refined saltpetre may be employed for manufacture in the case of a stoppage in the saltpetre refinery. In this case the dried salt is first ground under a pair of small stone edge-runners, fitted with scrapers to prevent the salt adhering to them, and then passed through a slope reel covered with 28-mesh wire, that which passes through the wire being used for mixing, the larger fragments being re-ground.

The sulphur is ground in quantities of 2½ cwts. at a time, under a pair of iron edge runners, also fitted with scrapers, and sifted in a slope reel covered with 32-mesh wire.

Charcoal, after being carefully hand picked to guard against the introduction of any fragments of foreign matter and underburnt knots of wood, is ground in a mill resembling a coffee-mill in action (Plate 7). It consists of a cone working in a cylinder, each being furnished with diagonal ribs or teeth, which are widely apart at top but approach closely together at the bottom. The charcoal which is shot in at the top passes out at the bottom into a slope-reel covered with 32-mesh wire, all fragments which do not pass through being transferred again to the mill.

An important caution must be mentioned in connexion with the grinding of charcoal. After being burnt it should be allowed to stand for a considerable time, ten days to a fortnight, before being ground, for when ground fresh after burning, the finely powdered charcoal absorbs and condenses oxygen so rapidly as to generate a great amount of heat, enough, in so bad a conductor, to cause spontaneous combustion. Instances of fires in gunpowder factories from this cause are on record, fresh ground charcoal having been left overnight in wooden bins or covered boxes.

The relative proportions of the three ingredients are weighed out in quantities of 50 lbs., that is to say, 37½ saltpetre (+ the extra weight for the moisture), 7½ charcoal, and 5 sulphur,* and transferred to the

* As previously mentioned, the quantity of saltpetre actually put to the 50 lb. charge is 38 lbs.; so that each nominal 50 lbs. charge (the quantity fixed as the maximum for incorporation at one time) is really 50½ lbs.

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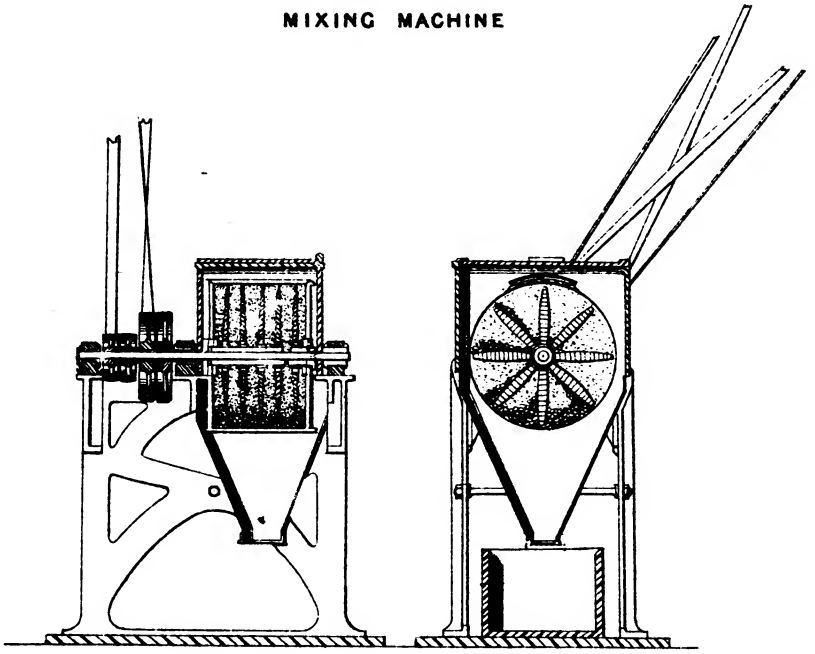
MIXING MACHINE



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mixing machine (see Plate 8). This consists of a hollow drum of gun metal, 1 ft. 6 in. wide by 2 ft. 9 in. in diameter, which is made to revolve at a speed of 40 revolutions per minute. The bearings of this drum are hollow to receive a shaft which passes through them. This shaft carries in the interior of the drum a series of 44 arms or fliers, the points of which just clear the interior of the drum, and revolves at twice the speed of the drum, and in the opposite direction. A 50 lb. bag of ingredients is emptied into the drum through a square opening at the top of it, and the drum, and shaft carrying the fliers being set in motion for five minutes, the saltpetre, sulphur, and charcoal are thoroughly mixed together. The opening at the bottom of the drum allows the mixed ingredients to fall down the shoot into a tub, from which they are transferred to an 8-mesh wire sieve placed over another shoot having a composition-bag placed beneath it. On the sieve the charge is carefully sifted by hand, to guard against any foreign matters, such as splinters of wood from the saltpetre bins, &c., passing into it, and falls through into the bags, in which it is tied up tightly, and transferred to the expense magazine or charge house ready for the incorporating mill.

A charge of fresh mixed ingredients is termed a *green charge.* Though not so easily ignited and slower in burning than gunpowder, it is, of course, explosive. The difference in effects may be well illustrated by flashing a small quantity of powder and an equal amount of green charge on thick plates of glass. The former will flash off, leaving no residue and doing the glass no injury ; the latter will puff off slowly and shiver the glass to pieces from the longer time the heat is applied to it, and will leave the fragments coated with particles of half decomposed saltpetre and sulphur. Accidents in mixing houses are fortunately rare; the last on record took place at Messrs. Hall's works at Faversham in 1867, resulting in the death of four men who were in the house at the time. The bodies of the victims of such accidents are generally found to be more burnt than those of men killed by explosions of gunpowder, from the more slow and lasting nature of the flame.

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CHAPTER VI.

INCORPORATION.

CONTENTS.—Importance of the process.—Excellence of powder depends mainly on its incorporation.—Test for sufficiency of incorporation.—"Flashing."—Object of incorporation.—How effected by the runners of the mill.—Description of the mill.—Number of mills at work at Waltham Abbey.—Modifications of the incorporating mill.—Instruments used by the millmen at the Royal Gunpowder Factory.—Description of the operation of incorporation.—Length of time required for the process.—Limit of quantity that can be milled at once.—Powers of a factory.—Examination of the finished charge.—Danger of the incorporating process.—Means taken at Waltham Abbey to prevent the spread of explosions.—The drenching apparatus.—Incombustible clothing of millmen.

INCORPORATION is unquestionably the most important of all the operations in the manufacture of gunpowder. Without it there would be no manufacture, for the charge of saltpetre, sulphur, and charcoal goes to the incorporating mill a mere mixture and leaves it gunpowder. Nothing that can be done to it afterwards will add to its strength or explosiveness; no future treatment can remedy defective incorporation. By incorporation is, of course, meant the long-continued grinding together of the ingredients, which blends them together and brings them into such close juxtaposition that they appear to form a new substance. Unless this be done perfectly, perfect mutual decomposition of the constituents of the gunpowder cannot be expected, on combustion. The more thoroughly it is effected the stronger will be the resulting gunpowder.

Upon the thorough and effectual incorporation which it receives depends mainly the excellence of English powder, which is allowed to surpass that of all other nations in strength. Great attention is paid to the process in this country, not only for military but for sporting purposes, and the most powerful mills are always used. It has been carried to the highest pitch of excellence,* and in many cases it is carried on for an unnecessary length of time; some of the finer sporting powders made in this country are said to be incorporated for 12 hours.

Provided the incorporating mill is sufficiently powerful, and is worked at a sufficient speed, a most thorough incorporation can be effected in a few hours, after which there is no object in continuing the process. It

* A writer (Dr. Wynter) in the Quarterly Review (vol. 103, p. 246) for 1858, states:—

"The improvements which have taken place in the manufacture of powder are very marked. About the year 1790, when powder was supplied to government wholly by contract, the regulation weight of charge for a cannon was half the weight of the ball; it is now less than one third: therefore two barrels are now used instead of three. Formerly powder had a range of 190 feet only; its range is now increased to 268 feet. This vast improvement is simply the consequence of the care with which the powder is worked and the attention bestowed on every detail of the mills since their direction fell into the hands of Colonel Tulloh, Col. Dickson, and Colonel Askwith, the present superintendent."

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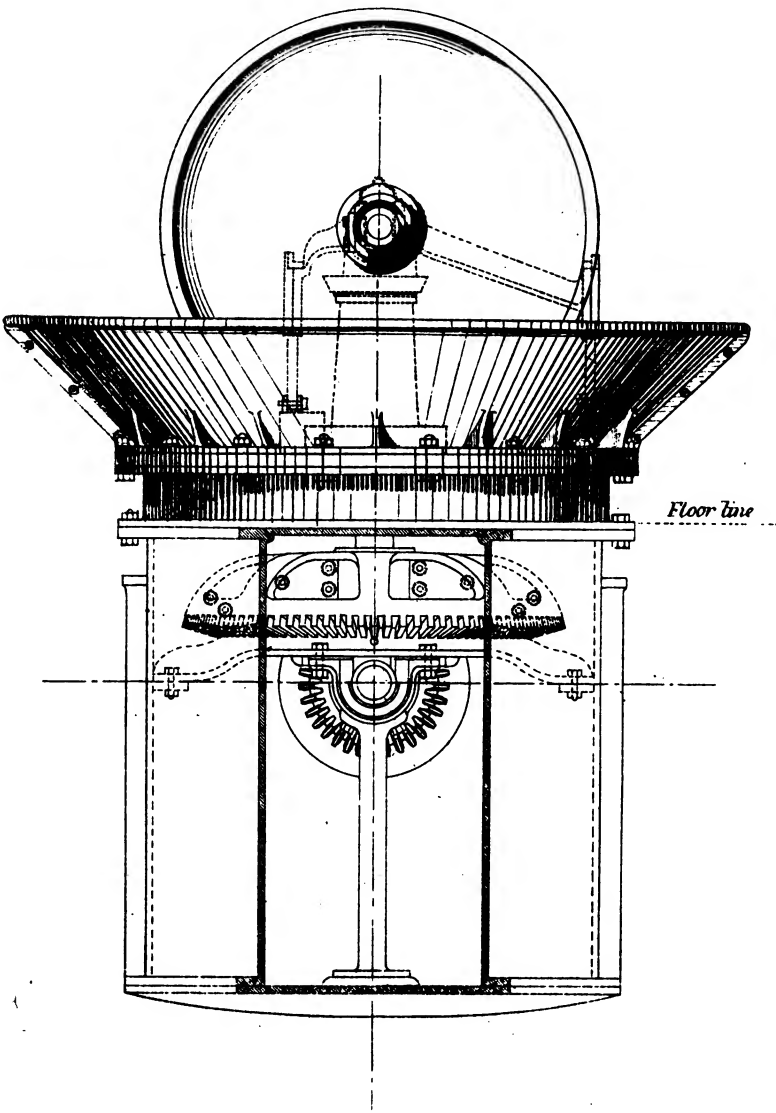
Plate 9.

INCORPORATING MILL



ELEVATION.

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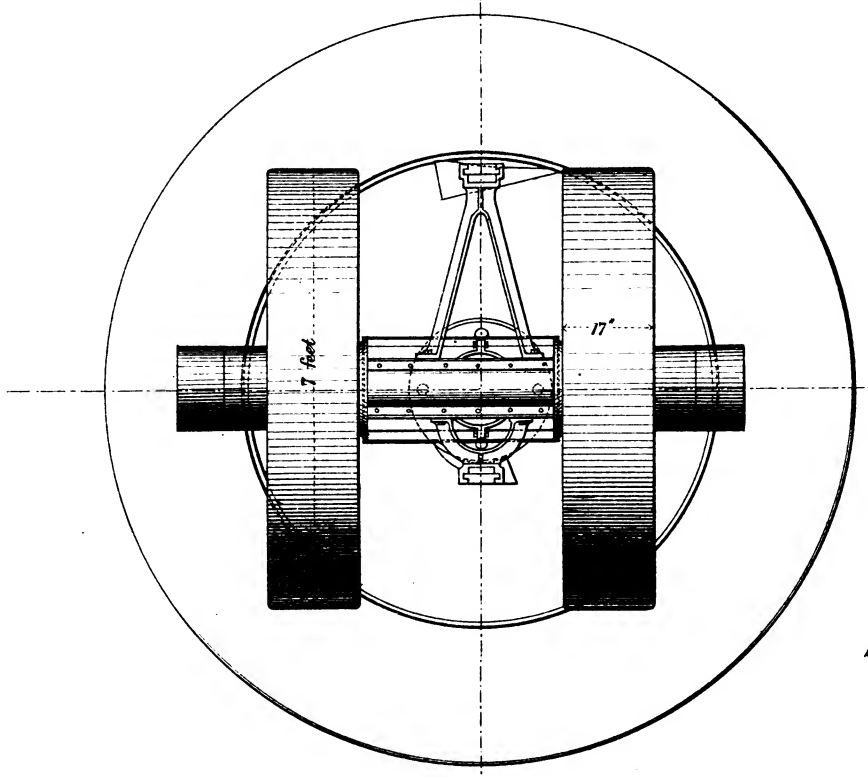
INCORPORATING MILL.



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PLAN.

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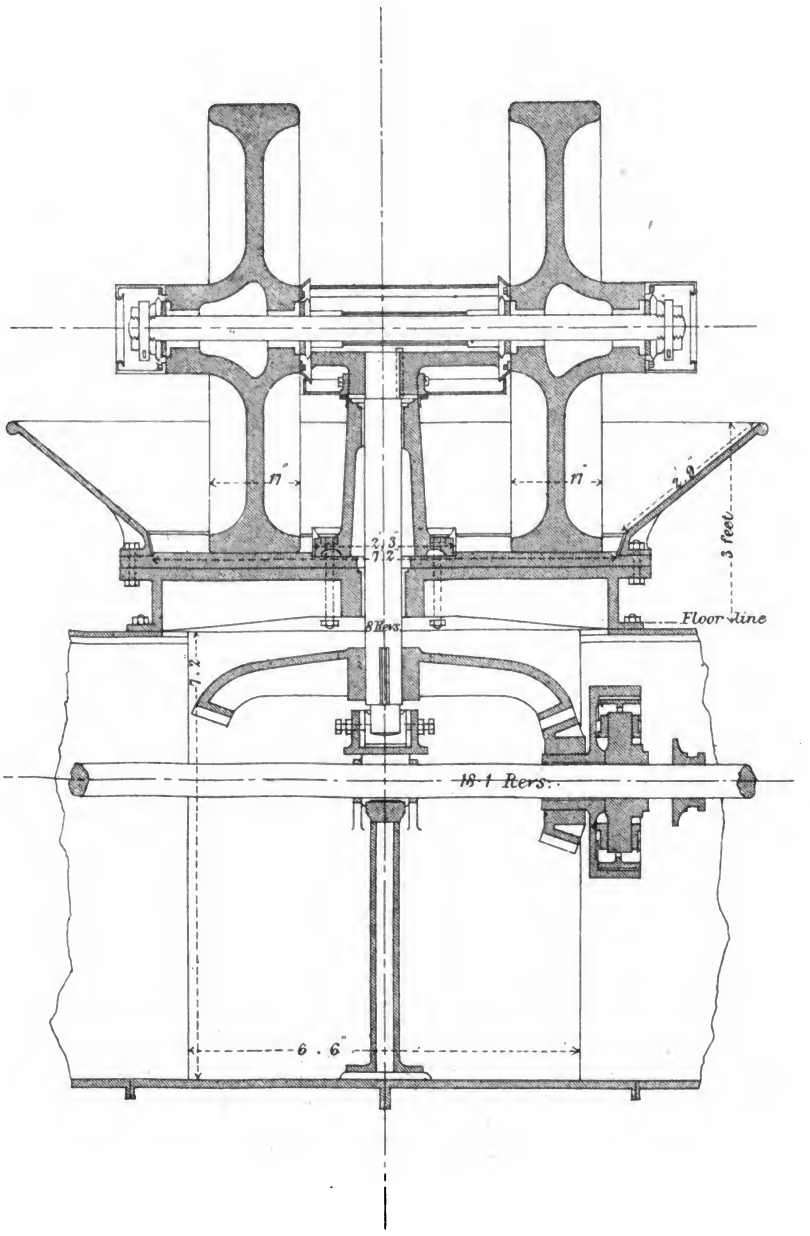
Plate II

INCORPORATING MILL



SECTION

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has indeed been suggested that, for cannon powder at least, we incorporate our materials too thoroughly, and thus render the powder too explosive. But imperfectly incorporated powder cannot fail to foul the gun under most circumstances. It therefore appears wiser to continue to incorporate the materials as thoroughly as possible, and to seek to reduce explosiveness not by damaging the gunpowder in quality, but by increasing its density and hardness, and by varying the shape and size of its constituent grains. We have said that an imperfectly incorporated powder cannot fail to foul the gun under most circumstances. What may be expected of such a powder may be at once seen by burning small quantities of different powders, varying in the amount of incorporation they have undergone, on plates of glass or porcelain. A perfectly made powder flashes off, leaving nothing but some smoke marks; an imperfectly worked powder will coat the plate with specks of undecomposed saltpetre. This "flashing test" is a simple and effectual way of ascertaining the amount of working which has been bestowed on the powder in the mills, and is the only safe and infallible test (provided it is left in the hands of an experienced person) of incorporation. There are very few foreign powders which stand it well, and no powder which does not, can be expected to shoot either strongly, uniformly, or cleanly.

Before describing the incorporating mills in use in English factories, it may be worth while to consider what they are intended to effect, and to judge therefrom how far they are well adapted for the purpose. Their action is intended, as has been already stated, to effect a close and intimate union between the saltpetre, the sulphur, and the charcoal. A chemist who had to unite two or more powdered substances as closely as possible would place them in a mortar, and work them round with the pestle for a length of time, trusting more to the rubbing and twisting action of it than to stamping. The gunpowder-maker endeavours to imitate this rolling and grinding together on a larger scale, and finds by experience that the most effectual way to do so is to grind the materials together under heavy edge-runners of stone or iron, which by their motion, a compound of rolling and twisting, soon work them into a homogeneous mass. The old stamping mills, in which the ingredients were subjected to long-continued stamping under pestles working in small mortars, have been out of use for many years in this country, though they are still employed in France and in other continental countries. The action of such mills has very little incorporating effect, and is moreover attended with even more risk than the mills used in this country. The same remark applies to the *moulins à tonneaux*, in which a partial incorporation is effected by placing the material in a revolving barrel or drum, along with some large metal or wooden balls. Such mills are much used abroad for pulverizing the ingredients, and occasionally for incorporation, but the fact is now generally admitted that the most effectual and speedy incorporation can be obtained with mills of the description now universal in England, and their employment is becoming general on the continent.

The incorporating mill (Plates 9, 10, and 11) consists of a pair of large heavy edge-runners, of iron or stone, which revolve on a strong circular bed, the bed being of course stone for the stone and iron for the iron runners. The runners are of various sizes, but must weigh from 3½ to 4 tons each. Some of the iron runners at Waltham Abbey are of large diameter, 7 feet, others about half this. It is now generally admitted that those of the smaller diameter are better than the larger, as the latter cause a greater twist on the bed, and are therefore more apt to cause accident. The face of the runners should be nearly flat, with a slight bevel towards

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the edge. The runners are connected together by a powerful spindle of wrought iron, which rests in brass bouches placed in the cross-head, so as to allow the spindle and runners to rise and fall according to the thickness or thinness of the layer of material on the bed. The spindle is placed in the cross-head, so as to bring one runner nearer to it than the other, and therefore to cause them to describe different paths when in motion. It is of the greatest importance that the spindle should have a large leverage on the runners as their weight is so great. They should therefore be cast with as long a socket for the spindle as possible, otherwise they will very soon work loose on it. An inspection of the two following illustrations will enable the reader to understand the details.

The cross-head is fixed on a vertical shaft, on which is fixed, underneath the flooring of the mill, a wheel driven by a pinion on the driving shaft which passes underneath the whole group of mills. By this arrangement the whole of the machinery is kept underneath, and out of reach of damage from explosion. The cross-head is fitted with a bracket on each side to carry a "plough," or wedge-shaped piece of wood shod with felt and leather, which travels round on the bed immediately in front of the runners, and thus keeps the composition from working away from them. The bed has a curb or edge round the outside and inside of the circular path described by the runners, that on the outside being formed by a sloping rim or casing fixed all round the bed, that on the inside by the circular base of the "cheese" or conical socket down which the vertical shaft of the cross-head passes. Both the inside and outside curbs have gun-metal rings round them for the ploughs to work against. Every fitting and bolt is arranged with the greatest care, so as neither to break nor become loose from the jolting of the mill, and thus drop into the charge. There are three groups of mills of the class described above at Waltham Abbey, driven by steam. In one, which consists of six pairs of runners, the driving power is at one end, the driving shaft passing along underneath the whole six, an objectionable arrangement; in the others, consisting of four pairs of runners each, the engine is placed in the centre, driving two pairs on each side. There is also a group of iron mills driven by water power with an auxiliary steam engine, and in addition 14 pairs of runners driven by water power; some of the latter are iron mills, some stone (the stone used being black Derbyshire limestone, which takes a very high polish) fitted with old-fashioned machinery placed overhead. There are therefore 32 pairs of runners in all, but generally only 29 pairs are worked at once, as six of the oldest mills are placed rather close together.

Various modifications of the incorporating mill have been proposed from time to time. The most important was a plan for keeping the runners and cross-head stationary, and causing the bed to revolve underneath them. This plan has the merit of greater safety to recommend it, but the mechanical difficulties in working it are very great. Another proposal was to heat the beds of all incorporating mills by steam, as heat is supposed to assist and hasten the process of incorporation, for some unknown reason.

The only instruments or tools allowed to be used by the millmen at Waltham Abbey are—a wooden rake, to distribute the charge over the bed; a "shover," or flat board on the end of a staff, to push up the charge from the bed from time to time; a copper spud, to be used in getting the charge off the bed when finished; a brush for brushing the materials into the centre of the bed; a wooden mallet to break up any

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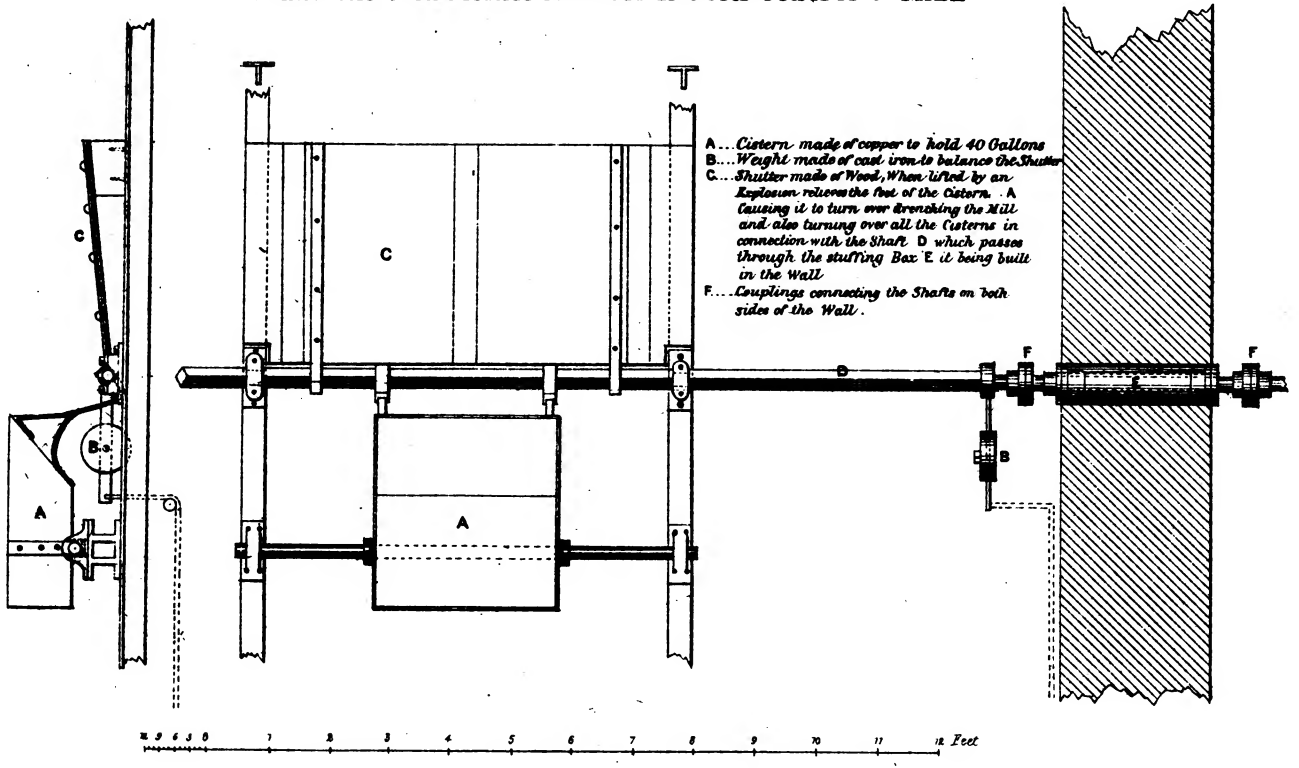
Plate 12.

PLAN AND ELEVATION OF THE

DRENCHING APPARATUS FOR INCORPORATING MILL



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caked powder which may adhere to the runners or bed; and a copper watering pot, used for watering the charge.

The operations connected with a charge are as follows:—The charges (either "green charges" from the mixing house, or dust charges from the dusting houses or granulating houses) come to the mills in wooden tubs, and are stored in strong expense magazines or charge houses. In all cases these charges have been carefully sifted before going to the mills, the green charges in the mixing houses after passing through the mixing machine, and the dust charges in the houses from which they come. This sifting is most necessary, as it is the only certain plan of preventing foreign matters getting into the mill bed. The millman takes the charge and throws one half on one side of the bed and the other on the other, and then with his rake and brush distributes it evenly over the mill bed. The runners are then moved round a quarter revolution, and the piece of mill cake left under the runners from the former charge is broken up and distributed over the fresh charge. This portion of mill cake is of course finished powder, and if the runners are left standing for any length of time with their whole weight on it, it becomes extremely hard. It should therefore always be broken up and distributed over the fresh charge, for if otherwise it may adhere to the bed, and being very hard may be the cause of so much friction as to cause explosion. It may be mentioned, however, that it is a much better plan to leave the runners on the portion of powder on which they stop, even from a Saturday night to a Sunday morning, than to attempt to run them off on to a leather placed on the mill bed, as must be done before the mill is washed out for repairs. There is so much risk of a portion of the runner coming down in contact with the bed, and thereby igniting some of the powder dust with which every crevice is filled, that it is better not to attempt it. Before starting the mill about two pints of water are sprinkled over the charge from the watering pot. The water used is condensed water from the steam stove, which is therefore pure. The runners are then started at a speed of about eight revolutions a minute. The millman does not remain in the mill, but only goes in from time to time to push up the charge from the bed with the "shover," and to add a little more water according to the state of the charge. From two to three pints are generally found to be necessary in very damp weather, and as many as eight or ten in very bright days. The watering (or "liquoring," as it is called) of the charge is always left to the millman's judgment; but arrangements are being made to lay down a regular scale of "liquor" for all mill charges, according to the indications of the hygrometer.

Cannon powder requires to be incorporated for three hours, all small-arm powder made with dogwood for five.* The maximum amount which is allowed by the Act of Parliament to be incorporated at one time under one pair of runners is 50 lbs. It is therefore easy to calculate the powers of a gunpowder factory. A pair of stone runners working night and day all year round, excluding Sundays, will turn out (deducting 10 per cent. of the product for short water, &c.) about 660 barrels of cannon, or about 330 barrels of small-arm, powder. A pair of iron runners driven by steam will produce (deducting 3 per cent. of the amount for repairs to machinery, &c.) about 950 barrels of cannon, or

* The times of incorporation vary with the power of the mills. Thus cannon powder requires 3½ hours working under stone runners weighing 3½ tons, and making 7½ revolutions a minute, but only 2½ under iron runners of 4 tons, making 8 revolutions a minute. Small arm (dogwood) powders require 5½ hours in the former mills, and 4 in the latter. All dust charges are worked ¾ hour in all mills.

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473 barrels of small-arm, powder. This is the greatest amount of work which can be obtained from them, no expedient can produce more, no extra time or work can be expended on the process. The powers of a gunpowder factory are therefore known, being regulated by the numbers of pairs of incorporating runners which it possesses. There is therefore no object whatever in accumulating large stores of saltpetre, sulphur, and wood for charcoal, with the idea of working them up when sudden pressure comes from the outbreak of war. The manufacture of gunpowder cannot be hastened, and even if it could, it would be most suicidal policy to rely on manufacture during the progress of war, for at any moment an explosion may happen which may cripple a factory for the greater part of a year.

As the process of incorporation approaches completion the charge requires to be carefully watched, in order to ensure each finished charge leaving the mill in as nearly as possible the same state as regards moisture. The appearance of the powder when finished depends mainly on the state in which the charges leave the mill. At Waltham Abbey the finished charge must have from 2 to 3 per cent. moisture. If too much moisture be present as the incorporation draws to a close, the charge must be repeatedly pushed up with the "shover;" if too little, some more must be added from the watering pot. The colour of the charge gives a very good indication of the amount of moisture present.

When the process is finished, the charge now known as "mill cake," being partly in the state of soft cake and partly of dust, is scraped and swept up from the mill bed, placed in wooden tubs, and transferred to the charge house to await inspection by the master-worker or his assistants. If the charges are found to be of a proper colour and consistency samples from each are taken, which after being roughly granulated by hand and dried, are flashed on a glass plate to ascertain the thoroughness of the incorporation which they have undergone. This flashing is more a matter of form than anything else, for the mill-cake seldom fails to give satisfactory results.

As incorporation is the most important of all the operations in the manufacture of gunpowder, so it is by far the most dangerous. Accidents in the subsequent processes, where large quantities of powder are subjected to treatment at one time, are fortunately rare, but in the incorporating mills they may be expected from time to time. It is hardly possible it can be otherwise, considering the enormous friction to which the powder is subjected in them. The amount of water added to the charge does not, as is commonly supposed, reduce the ingredients to a pasty mass and so lessen their explosiveness; on the contrary, the charge when it approaches completion is highly explosive. If a larger amount of water were added the saltpetre would be partly dissolved, and all the incorporation previously effected would be undone. It is difficult to conjecture how accidents do happen, unless it be from the charge adhering to the runners and leaving the bed bare, in which case the friction between the runner and the bed is so great as to cause a spark. Of course the more obvious causes of accident, such as some foreign body falling into the bed, are not alluded to here, but only those causes which are as yet unknown, and which no amount of vigilance can altogether avert. A careful register of explosions of incorporating mills shows that no particular season is more free from them than another.

Admitting, therefore, that occasional explosions in the incorporating mills are inevitable, the object of the manufacturer must be to render them as harmless as possible. As such mills are generally built in groups, an explosion in one is very apt to spread amongst all the others round it, particularly as the roofs of all are saturated with powder dust.

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To prevent this a drenching apparatus, of which the accompanying plate (Plate 12) is a representation, is erected over each pair of runners.

The apparatus consists of a large shutter pivoted on a spindle which runs through the whole group of mills. To this spindle the shutter in each mill is attached, and the spindle passes through bearings in the partition walls, so that the lifting of one shutter lifts all the others. Balanced on the pivot edge of the shutter is a large copper vessel full of water. This vessel is so arranged that the slightest lift of the shutter capsizes its contents into the bed of the mill beneath it. An explosion in one mill therefore lifts the shutter above it, and throws down the water into the mill bed, and though of course too late to do any good in the mill which has exploded, the movement of the shutter turns the spindle and drowns the charges in all the adjacent mills, and thus saves them from explosion. There is also an arrangement by which the millman can (in case of an explosion in the immediate neighbourhood) pull over the vessel of water from outside. This drenching apparatus is found to answer very well at Waltham Abbey; and though in some cases the flash of an explosion may be quicker than the action of the apparatus, and so anticipate it, yet there is no doubt it is the means of saving a great amount of property.

The explosion of a green charge does not in some cases do much damage to the structure of the mill or the machinery; that of a worked charge is very violent, and leaves generally no part of the structure standing. Consequently all mills are made of a very strong framework covered with light boards, which can be quickly replaced if destroyed by an explosion.

The millmen are specially protected by suits of incombustible clothing, and leather caps and gloves, the latter having flaps to cover the neck and wrists. None of these would have much effect in shielding them if actually in the mill when an explosion happened; but they have proved of great service in protecting the men from burns when near a mill that exploded. Fortunately the men do not require to be always in the mills; on the contrary, they only enter them from time to time for a minute or so, either to "liquor" the charge, or to see that all is going on well.

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CHAPTER VII.

BREAKING-DOWN AND PRESSING.

CONTENTS.—State in which the powder leaves the incorporating mills.—Necessity for converting it into grains.—Formerly done by damping the mill-cake and passing it through sieves.—Objections to this plan.—Only perfect way of forming grains is first by pressing.—Why gunpowder must be reduced to meal before pressing.—The "breaking-down machine."—Description.—Pressing.—Description of the hydraulic press used at Waltham Abbey.—Filling the press-box.—Placing it under the ram.—How the amount of pressure is estimated.—Stopping the pressure and unloading.—Pressing without a press-box.—Description of the process.—Difficulty of attaining uniformity of results in pressing.—Great importance of attaining uniformity.—Best method of securing uniformity.—Varying resisting powers of the meal when subjected to pressure.—Consequent variations of time in pressing.—Quantity of powder which may be pressed at one time.—Object of the restriction as to quantity.—Accidents in press houses.

GUNPOWDER leaves the incorporating mill partly in the state of soft cake, partly dust. The cake hardens very considerably if allowed to stand for a few days. In this form it would be, of course, quite unfit for use. The cake may indeed be broken up into grains, as is done in many countries, but such grain is too soft to stand much handling or transport without crumbling to dust. Powder made from mill-cake will always be found to be dusty, and such powder must always be irregular in action. It will also be much more liable to absorb moisture, and therefore to cake and become lumpy.

To ensure uniformity and good keeping qualities, and freedom from dust, powder must be converted into firm grains. The "corning" or graining of gunpowder has been recognized as one of the most important features in the manufacture from a very early period. The earlier makers probably damped the incorporated materials till they acquired a certain consistence, and then forced the mass through sieves, thus forming granular fragments which were afterwards hardened by drying. Strange though it may appear, powder is made in this fashion in some out-of-the way places in England at the present day. There is no difficulty in forming good hard grains in the manner described, but a little reflection will show that it is at the sacrifice of the incorporation which has been previously effected. The moisture added partly solves the saltpetre, which in drying forms a hard external surface to the grains.

The only perfect way of converting gunpowder into serviceable grains without in any degree whatever interfering with the perfect incorporation of the ingredients, is first to compress the soft material into hard masses by pressure alone, and then to crush up these masses into the description of grain required. The object of pressing, then, is to convert the soft dusty mass of incorporated ingredients, now gunpowder, into hard cakes of the particular density which is found to give the best results when the powder is finished. Once the cakes are formed they can be subsequently broken up by various contrivances

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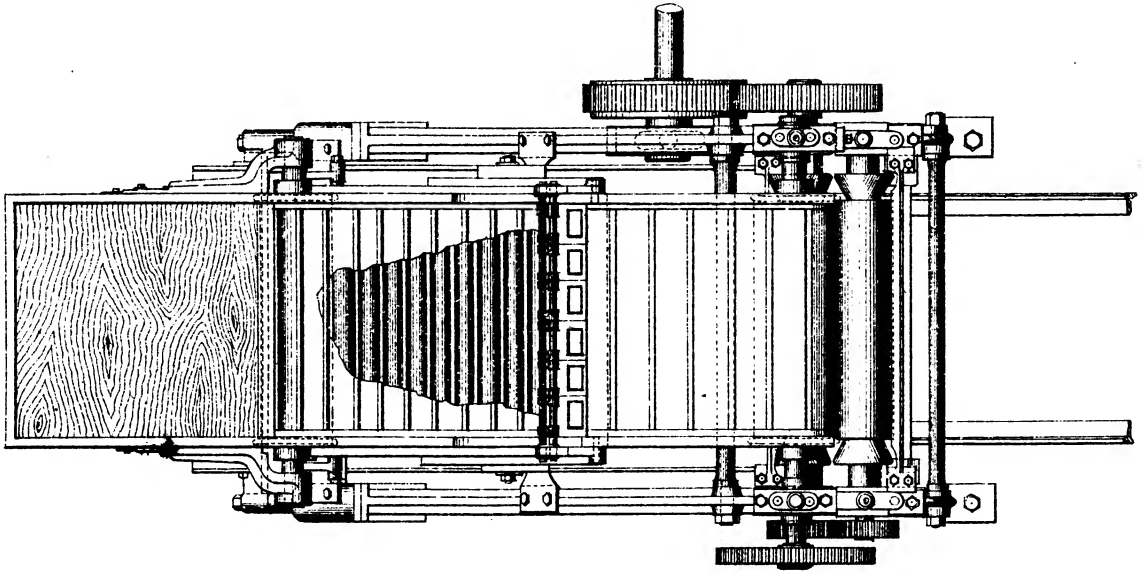
BREAKING-DOWN MACHINE.



PLAN.

Scale ½ Inch to a Foot:

Inches 12 9 6 3 0 1 2 3 4 5 Feet.

Face P. 47.

Vincent Brooks, Day & Son, Lith.

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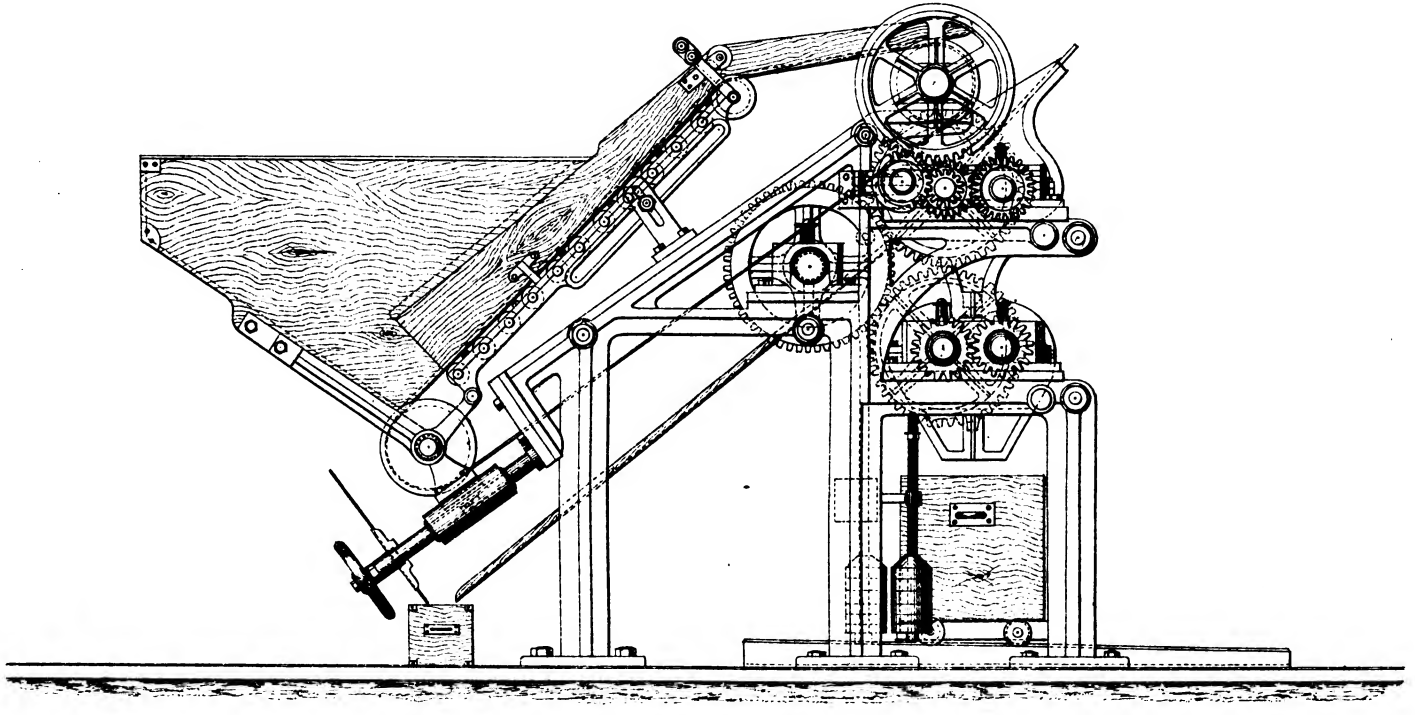
BREAKING-DOWN MACHINE.



ELEVATION.

Scale ½ Inch to a Foot.

Inches 12 9 6 3 0 1 2 3 4 5 Feet

Face P. 44.

Vincent Brooks, Day & Son, Lith.

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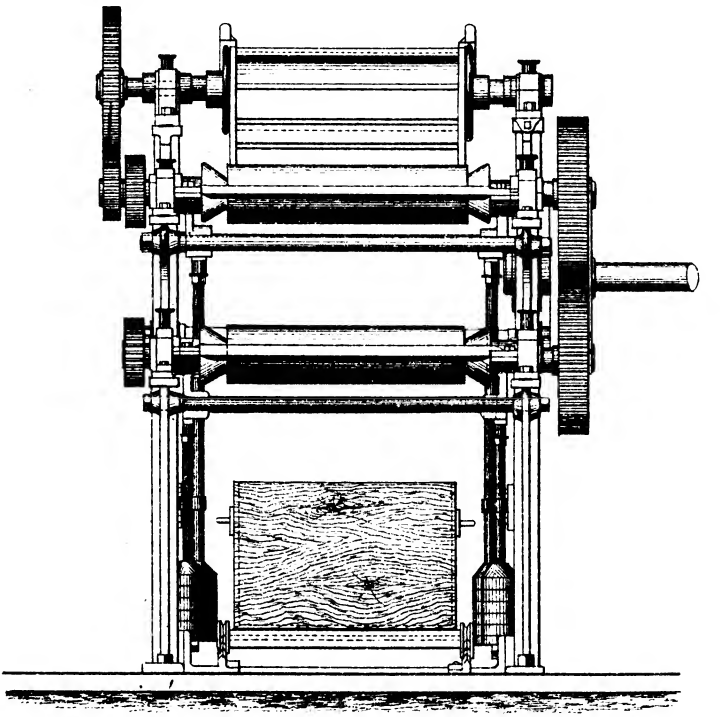
Plate 15.

BREAKING-DOWN MACHINE.



END ELEVATION.

Scale ½ Inch to a Foot.

Inches 12 9 6 3 0 1 2 3 4 5 Feet.

Vincent Brooks, Day & Son Lith.

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into grains of any size, all of which will have a uniform density and hardness, and which can be freed from dust, and glazed and polished so as to bear handling and transport without breaking or crumbling.

Gunpowder is generally pressed in layers between plates of gun metal or copper in a hydraulic press. Screw presses are still in use in many factories, and there are different ways of placing the powder in the presses used. The best results are found to be obtained at Waltham Abbey by pressing in thin layers. The details of the process will be described further on, but it is merely necessary to say here that the gun-metal plates between which the powder is placed are, when the press is being filled, placed on their edges and the powder thrown in between them. As they stand closely together ($\frac{1}{8}$ inch apart) it follows that to ensure the powder finding its way down between them it must be reduced to a tolerably fine state of division. If taken direct to the press from the mills the cake would not enter between the press plates. A preliminary operation is therefore necessary, viz., *breaking down.*

Breaking down is not a primary operation in the manufacture, but only a preparation for pressing. Its object is to reduce the mill cake, that is, the incorporated ingredients as they leave the mill, to a fine meal, in order that it may be readily placed in the press. If the powder is to be pressed in very thick cakes it would not require breaking down at all.

The breaking-down machine (see Plates 13, 14, and 15) consists of two pairs of grooved rollers of gun metal placed in a frame, the one pair directly above the other. They are grooved longitudinal to get a better hold of the mill cake. One roller of each pair works in a sliding bearing, and is held at a proper distance from the other by a weighted lever. This arrangement admits of each pair opening out a little if too large a quantity of the cake is drawn in between them. Attached to the machine is a large hopper capable of containing five barrels* of mill cake. An endless band of strong canvas, having transverse strips of leather sewed on to it, works through an opening at the bottom of the hopper up to the top of the machine, by means of which a regular supply of the cake is carried up and dropped in between the rollers, which crush it up into fine meal. The meal falls through the second pair of rollers, which reduce to dust any fragment which may have escaped the action of the first pair, and finally falls into wooden tubs placed underneath to receive it. It is then ready for direct transfer to the press. Too long an interval must not elapse between the breaking-down and pressing, for the meal, which should contain a considerable amount of moisture (from 2 to 3 per cent.), will soon cake together again and become lumpy.

The most convenient form of hydraulic gunpowder-press is that shown in the following illustrations (see Plates 16 and 17). The details of the apparatus require little explanation. The press box is made of gun metal, lined inside and out with oak boards, and is of great strength. The bottom and one side are permanently attached to each other. The other three sides are hinged to the bottom, so that they can be opened out to facilitate unloading. When closed they are secured with short, very strong, coarse-threaded screws of gun metal. The box has two projecting gun-metal claws which hinge on to a fixed horizontal rod of the same metal, so that the box can be turned on it, on to the table of the hydraulic press, when filled and ready for pressing, or outwards when it has to be unloaded. It is loaded as follows :—Being first turned down on its side, the open top is closed temporarily with a piece of board which is fitted to it. What is now the uppermost side is

* A "barrel" always means a barrel of 100 lbs., unless otherwise specified.

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uncovered and raised, and the other two sides are fastened in their places. Gun-metal racks to hold the press plates, having perpendicular grooves in them ½ inch apart, are then slid in on each side, and the plates being put in, the meal from the breaking-down machine is shovelled in and falls down readily between the plates till the box is full; the racks are then drawn out, leaving the plates free with layers of powder between them. The excess of powder being carefully swept off the edge of the box, the upper side is lowered and screwed to the other three, an overhead block and tackle is made fast to the gun-metal eye on the side of the box, and the box is turned over on to the press table.

The box now stands on its bottom, and the temporary board with which the top has been closed during charging being lifted off, the powder and plates will be found to have settled down several inches by their own weight. The vacant space at the top is filled up by shovelling in a few more layers of meal, placing a plate by hand on each in succession till the press box is quite full. As the box is now standing on the table of the ram, all that remains to be done is to run the overhead block (which exactly fits into the press box) into its place directly over and nearly touching the contents of the box, to secure it there, and to apply the pressure until the box rises to a sufficient height.

The pumps which are driven by water power are in another building, separated from the press house by large traverses. In this building the workmen remain while the pumps are at work, but the foreman before leaving the press house must see that the block enters the box fairly, and should go in from time to time to see that everything is working well.

The amount of pressure to be given to the contents of the press box is always estimated at Waltham Abbey by the distance to which the overhead block enters the press box. This is a rough but tolerably exact method of regulating pressure, for if the same amount of pressure (tons per square foot) be applied to the contents of two press boxes, and if the contents of the one be compressed into half the space those of the first are, it is but reasonable to suppose that the contents of the first will be twice as dense as those of the second. This question will be more fully treated hereafter. R.L.G. is compressed 13½ and R.F.G. 11½ inches, or thereabouts.

Each press is provided with two pumps, a large and a small one. At first both pumps work, but as the pressure increases the larger one is thrown out of work by a self-acting arrangement, and the smaller one continues working alone.

A catch which can be adjusted to any height, and which holds back a kind of trigger, is fixed on the overhead block in such a way that whenever the block has entered the box to the depth required the catch comes in contact with the rising edge of the press box, and relieves the trigger, which rings a bell in the pump room. The pumps are then stopped, the escape valve opened, and the press table carrying the press box allowed to descend. The workmen then re-enter the press house and proceed to unload the box. The overhead block is first run out of the way, and the block and tackle being attached to the box it is turned over on its side. The fixing screws are now taken out of their sockets, and the three hinged sides of the boxes opened out, leaving the powder and press plates standing in a solid mass. Each plate, with a layer of hard slate-like cake adhering to it, is separated from the one beneath it, and being lifted into a wooden bin, gets a few knocks with a wooden mallet which cause the cake to fall off in irregular fragments, which are broken into pieces of the size of a man's hand, shovelled into tubs, and removed to an expense magazine.

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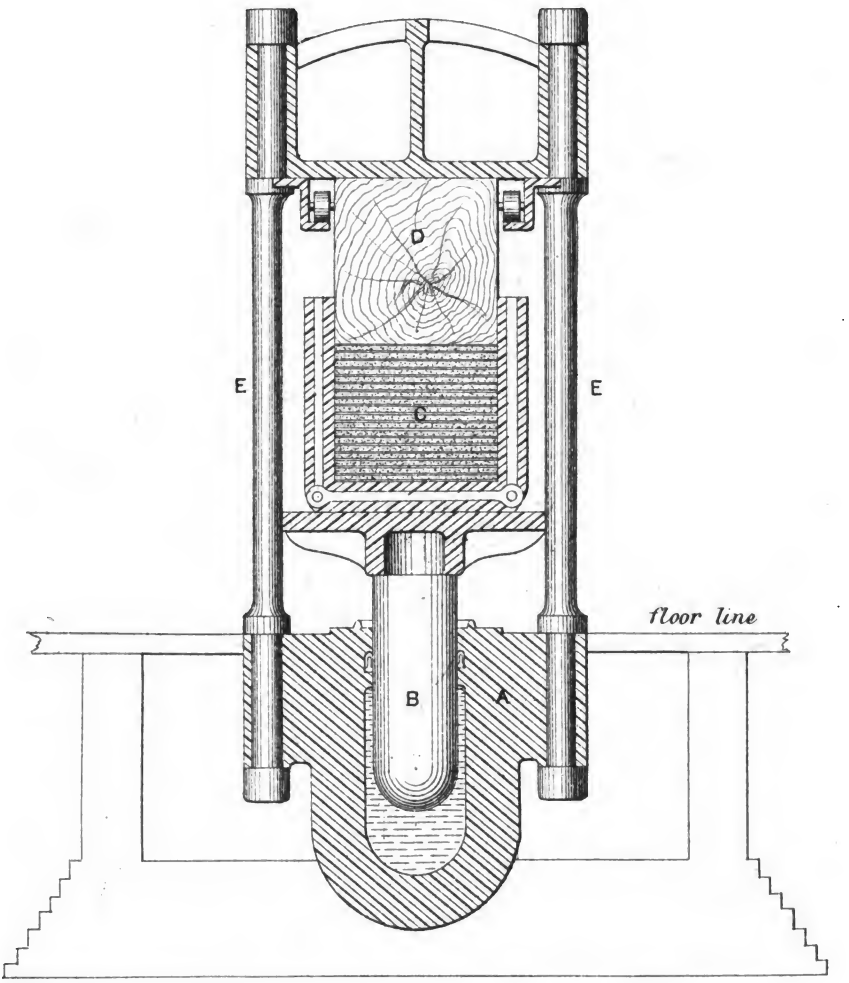
Plate 16.

PRESS



ELEVATION AND SECTION
SHOWING PRESS IN ACTION.

A *Cylinder* B. *Ram* C *Press-box*
D *Overhead block* E.E *Standard*

Scale $\frac{1}{27}$

Vincent Brooks Day & Son. Lith.

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Powder is occasionally pressed at Waltham Abbey without making use of the press box at all, in the manner followed in France. This is only done when very great accuracy is required. It is obvious that if the pressure applied to powder be regulated according to the distance to which the meal is to be compressed to ensure uniformity of results, not only must each pressing be carried on to the same distance, but there must be *exactly the same quantity of material* subjected to the process each time. There are other conditions also which affect the density of the resulting press cake, of which we shall speak hereafter, but meanwhile it is enough to remember that to obtain pressings of equal density equal quantities of powder meal must be compressed equal distances. To ensure greater exactness in the amount subjected to pressure each time the French plan has been occasionally used. It is carried out as follows :—

A sheet of stout canvas, the same size as a press plate, is laid on the table of the hydraulic press. On this is placed a wooden frame of the depth of the layers of meal which require to be pressed, generally from $\frac{3}{4}$ to $1\frac{1}{2}$ inches. Powder meal is shovelled into the frame till it is full, and the excess carefully struck off by drawing a wooden rod over the edge of the frame. The frame is then lifted off, leaving a layer of meal of the required thickness on the press table. On this layer is first placed another sheet of canvas, then a gun-metal press plate, and finally another sheet of canvass, on which a fresh layer is spread in a similar manner, and so on till a pile of layers of powder, separated by canvass and gun-metal plates, is built up to the level of the under surface of the overhead block. The pressure is applied in the usual way. This system of pressing, though slower than the usual system, appears to offer some decided advantages.

It is a matter of considerable difficulty to ensure uniformity of results in pressing powder. It is of the highest importance that the density obtained should be uniform, for recent experiments have proved conclusively that the qualities and explosive effect of gunpowder are materially affected by comparatively slight variations in density. For instance, a difference of ·05 in the density of the charges may affect the initial velocity of a 12 lb. shot, fired with a 1 lb. charge, to the extent of about 50 feet a second. No difference between the two powders may be perceptible ; they may be made identical in every other respect, and may even cube alike ; in fact, be undistinguishable from each other by any ordinary test ; but when used at practice they could not give the same results, and the discrepancies would, in the event of a possibility of difference in the quality of the powder being overlooked, be, in all probability, attributed to some shortcoming of the gun or projectile. Since the introduction of the mercury densimeter it has become well known that great differences exist in the densities of the present store of gunpowder, and a long series of observations with the electro-ballistic apparatus has established the fact that it is perfectly possible to manufacture powder of uniform density, and that such powder will give accurate and uniform results, both as regards pressure in the gun and (consequently) velocity imparted to the shot. The density of powder is given in the press ; the importance of accuracy in pressing, on which the shooting qualities of powder therefore entirely, or at least mainly, depend, is evident. Unfortunately, with the present appliances, it is a matter of very considerable difficulty, to press two pressings to exactly the same density.

There are two ways of estimating the compression communicated to the contents of the press box. The first is by the gauge attached to the pumps, which shows at any moment the actual pressure per square foot and square inch on the cylinder of the press. The other is by observing

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the *effect* of the pressure applied, that is to say, the extent to which the contents of the box have been compressed, as shown by the distance to which the block has been forced into the press box. Now if equal pressure had always equal effects on gunpowder meal, there would be an end to the difficulty, for the escape valve of the hydraulic press can always be arranged so as to stop the action of the press the moment a certain pressure per square foot or inch of the surface of the powder is reached. But the meal possesses varying degrees of elasticity and resistance to pressure, depending to a great extent on the moisture it contains, and, as far as can be judged by experience, on the state of the atmosphere at the time. A pressure of 70 tons per square foot may therefore be applied to the contents of the press box, and the press cake, when dried and examined in the densimeter, may show a density of 1·74. The next pressing made, as far as one can judge, under exactly the same circumstances, may have as low a density as 1·64, in consequence of the elasticity of the meal refusing to yield to compression. The safest rule to go by is, therefore, the distance, and if all conditions could be made the same in each experiment,—if equal quantities of meal, containing equal quantities of moisture, could be compressed to the same amount, in equal times and under the same atmospheric conditions,—there is little doubt that tolerable uniformity of density would be attainable. But it must be always a matter of the greatest difficulty to fulfil all these conditions exactly. In the first place, the moisture in the broken-down meal depends mainly on the amount of "liquoring" the charges have received in the incorporating mills. This is left at present to the judgment of the workman, who is guided by the state of the weather.* As previously remarked, the proposed establishment of a code of rules for moistening the charges according to the indications of the hygrometer, may effect an improvement in this matter. But though the charges may be uniform as regards moisture on leaving the mills, it is obvious that variations of temperature between the days of incorporation and pressing will affect them unequally. In the next place, the *bulk* of the meal is of course affected by the moisture contained in it, so that, fill the press box as carefully as we can, we do not get equal quantities to be subjected to pressure each time.

If the quantities operated on were very small, it might be possible to devise some method of equalizing the moisture contained in them; but when 800 lbs. is required to fill a press box it becomes a much more difficult matter.

The conditions of equal times for pressing to equal distances will of course be impossible if the contents of the box possess unequal yielding properties. The differences experienced in this respect are very remarkable. At one time the meal seems to consolidate at once, at another to withstand the pressure for a much longer time before settling together. Sometimes, also, it seems under equal pressures to part with its moisture much more readily than at others; in the former case the moisture is actually squeezed out of the cake, and can be seen in drops on its edges when pressing without a box; in the latter, it is retained in the substance of the cake, and is only expelled in drying. An observer who tests the densities of the press cake as it comes from the press, may therefore be led into very serious error in estimating what the density of the powder made from it will be. For if two specimens of press cake, one of which has parted with the greater portion of its moisture in the press, and the other of which has retained it, be tested

* The charges from all the mills being, however, thoroughly intermingled in the process of breaking-down, the meal as a rule is very uniform.

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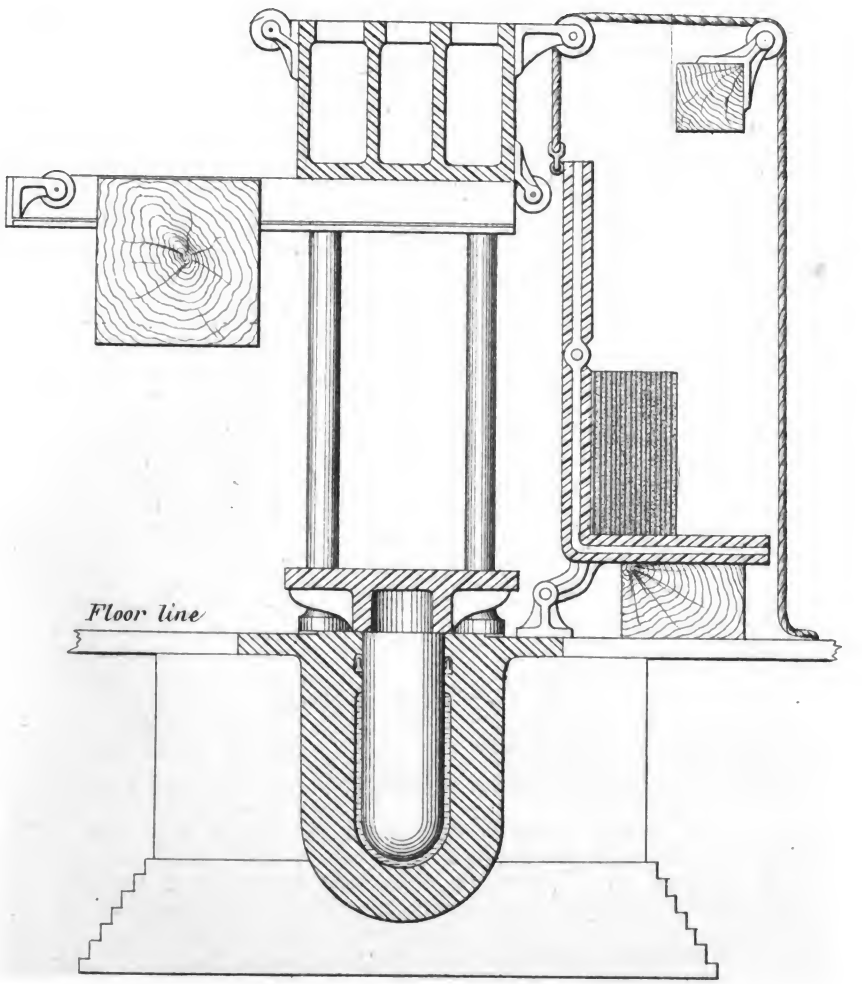
Plate 17.

PRESS



ELEVATION AND SECTION

SHOWING PRESS PARTLY UNLOADED

Scale $\frac{1}{27}$.

Vincent Brooks Day & Son Lith.

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then and there in the densimeter, they may both have the same figure of density ; but when dried in the oven, the former parts with little or no water, and when re-examined for density may give an almost identical result with what it did at first; but the second having parted with a large per-centage of moisture, may lose as much as ·10. It is therefore absolutely necessary, when examining the densities of press cake, in order to ascertain if it is fitted for the manufacture of a particular powder, to have it previously dried.

It is found in practice at the Royal Gunpowder Factory, that though absolute uniformity cannot be guaranteed in pressing, very tolerably close results can be obtained. To attain absolute uniformity in the finished powder, the density of every pressing, after it has been converted into grain, sometimes of every glazing, is taken, and the different pressings or glazings are then mixed in the proportions to give the density required. Thus if R.L.G. be in hand, and the density fixed for the powder be 1·67, and the densities of two pressings be found to be 1·70 and 1·64, they would be mixed in equal proportions, and would give a powder of 1·67 density.* More particulars on these points will be given when the question of proof is considered.

The quantity of powder which may be subjected to pressure at one time is limited by the Gunpowder Act to 10 cwt., and not more than twice this quantity is allowed to be in the house where the operation is carried on. The object of the limitation is, of course, to prevent an explosion in a press house spreading to other buildings in the neighbourhood; but as no rules are laid down for the distances of such buildings the limitations are of no use in preventing accident. Explosions of press houses are by no means uncommon, and such accidents, if happening when the powder is being subjected to pressure, are the most violent and destructive of all explosions in gunpowder factories. Of 29 great explosions which happened in powder works between May 1858 and June 1870 (putting the frequent minor explosions of incorporating mills out of the question), no fewer than eight originated in press houses, viz., one at Messrs. Curtis and Harvey's at Hounslow in 1859; another at the Ballincollig works in 1861; a third at Messrs. Sharp's factory at Chilworth in 1864; a fourth at the Ewell works in 1865; a fifth at Faversham in 1867; a sixth at the same works in 1868, but in this case repairs to the machinery were going on; a seventh at the Blackbeck works near Windermere in 1869; and an eighth at the Kames works in Argyleshire in the present year, entailing the loss of 39 persons' lives.

Since these words were written, a disastrous explosion happened on the 16th June 1870, in the press house at the Lower Island works, Waltham Abbey, which resulted in the death of five persons. From the statement of one of the men who survived the accident a short time, it appears that they were unloading the press at the time, and making use of the copper chisel (or spud) to separate the press plates.†

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* Powders which differ to a great extent in density are never mixed.

† On the subject of accidents in powder manufactories, the reader is referred to an article on gunpowder contributed by the writer to the Quarterly Review in July 1868.

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CHAPTER VIII.

THE DENSITY AND HARDNESS OF GUNPOWDER; THE EXTENT TO WHICH VARIATIONS OF THESE AFFECT THE QUALITIES OF THE POWDER.

CONTENTS.—The particular qualities of gunpowder which must be taken into consideration.—Explosiveness, or rate of burning of powder.—Distinction between strength and explosiveness.—Best way to look at the question.—Density of powder distinct from hardness.—Meaning of the terms.—Both imparted in pressing.—How they are tested.—Great importance of the question of density at present.—Old way of testing.—The cube-box.—Results obtained with it sometimes fallacious.—Slight variations in density at once detected by the densimeter.—Very great effects which such variations may exercise on the action of the powder.—As exemplified in the old mortar and new electro-ballistic proof.—How fouling is affected by the density of the powder used.—A small-arm question.—Tendency of small-bores to foul.—Not the fault of the arms but of the powder.—How fouling arises.—Trials of powder for the Martini-Henry rifle.—Messrs. Curtis and Harvey's No. 6, the "M.H.," and the "K."—The keeping qualities of powder, to what extent they are affected by density and hardness.

BEFORE attempting to point out to what extent the qualities of gunpowder are affected by its density and hardness, it will be necessary to consider—

1st. What are the qualities of gunpowder alluded to; and,

2nd. What are the other conditions besides variations in density which may affect them.

The only qualities of gunpowder with which it is necessary at present to concern ourselves are—

1st. Explosiveness.

2nd. Freedom from fouling.

3rd. Keeping qualities, that is, power to withstand disintegration, from transport and absorption of moisture.

Provided a powder comes up to the standard in these three points it will fulfil everything that the soldier expects of it.

By *explosiveness* is meant the *rate* at which the powder burns; in other words, the speed at which the substance is converted into gas when ignited. It is of the highest importance that this term should be clearly understood, for on the greater or less explosiveness of gunpowder depends entirely its fitness for modern arms. The term explosiveness is not altogether synonymous with strength. For instance, there may be two samples of powder, the first of which when completely burnt might yield a *larger portion of gas*, though at a *slower rate* than the other. The former might, and probably would, exercise a greater force in blasting operations, where the powder is confined in the centre of a mass of rock; while the latter would probably, from its more sudden action, propel a shell further from a mortar. The *strength* of a powder is a very vague term, for as yet there is no means of determining which of a number of samples of powder is literally the *strongest* under all circumstances. One powder may communicate a higher velocity to a

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shot fired from a gun than another which might produce a greater effect than the first if employed for a different purpose under totally different conditions. The strongest powder would manifestly be the powder which would produce the greatest effect under all conditions.

The most convenient light in which to regard this question for practical purposes is this—there is a certain *force* exerted by the pressure of fired gunpowder, and there is a certain *time* during which the force is being generated. Assume that the force (*i.e.* the strength) of all English powders of the same class is equal, that is, that all samples of powders made with the same ingredients, and equally well incorporated, will when fired produce equal volumes of gas,* in other words, will be equally strong, but that all will vary in *explosiveness*, in other words, in *quickness*, according to the physical qualities of the gunpowder grain. Experiment proves that the above assumption very nearly expresses the real facts of the case, for two samples of the same gunpowder meal after incorporation (which would if fired in equal quantities produce exactly equal results) may be converted by pressure and other treatment into different powders, of which 2 oz. of the one will propel a 68-pr. shot from an 8-inch mortar 300 feet, while 2 oz. of the other will scarcely project it out of the mortar.

The other qualities, viz., freedom from fouling and power to withstand transport and absorption of moisture, do not require any particular explanation here.

Now the qualities of powder, as above enumerated, are mainly dependent on—

1st. Its density.

2nd. Its hardness.

3rd. The size and shape of its grains.

4th. The amount of polish or glaze to which the grains have been subjected.

The question how far the qualities of powder are affected by its density and hardness, other things being equal, we purpose to discuss at present. The effects which the size and shape of its grains exercise on it will be postponed till after the manufacture of grain powder has been described, and the slight effect which glazing or polishing the grains produces will be noticed after the description of that process.

The meaning of the terms density and hardness must be clearly understood before going further. By the former is meant the quantity of matter actually present in a certain bulk of the powder; thus, if different quantities of powder meal be compressed into equal bulks, say, for example, into cylinders of equal size, the cylinder which contained the most meal will have received the greatest amount of pressure to reduce the larger amount of meal to the size required, and will be the densest, that is, will contain more actual matter than any of the other cylinders. The term hardness explains itself, it has not necessarily a relation to density, for a substance may be very hard and yet possess little density. In the case of gunpowder, a powder with a very hard surface may be really less dense than another the surface of which is softer; of course very high density cannot be communicated to the meal without at the same time rendering it very hard; but it must be borne in mind that a hard surface can be given to powder without rendering it dense. The distinction between the two will be better remembered by recalling the methods by which the

* The *rate* of combustion will of course affect the volume of gas generated, under all circumstances, from the different amounts of heat generated, which cause corresponding expansions of the volumes of gas.

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two qualities are communicated ; both are imparted in the operation of pressing, and it is for this reason that the subject is introduced in this place. Increase of density can only be given by *compressing the meal into a smaller bulk*, while increase of hardness can be communicated by *pressing the meal while in a moist condition.*

The absolute density of any sample of gunpowder can be easily and accurately ascertained, but as yet there is no means of testing the quality of hardness further than by breaking the powder between the fingers. It is therefore a matter of the greatest difficulty to decide which of two powders which closely resemble each other in physical qualities is the hardest ; the decision had better always be left to a practical gunpowder-maker who has had long experience in actual manufacture. Nothing but long practice can communicate the power of detecting slight variations in hardness of grain, or the knowledge of the extent to which such variations are likely to affect the qualities of the gunpowder. Familiarity with such subjects is most of all necessary in the examination of powder returned into store after being landed from ships, or emptied from cartridges, &c. No one but a person thoroughly familiar with the manufacture in all its stages can possibly decide what extent of deterioration a sample of powder has undergone, or what amount of repair, in the way of re-dusting or otherwise, it is capable of standing.

The question of the density of gunpowder has received very little attention till within the last few years. Artillerymen of all ages have certainly been aware that powders of different densities produce different results ; but it is only recently that it has been possible to detect slight variations in density, and to observe accurately the results such differences actually produce. Recent experiments have proved conclusively that the density is the quality of all others which produces the most important variations in the powers of gunpowder, and that it is hopeless to expect uniformity of effect unless uniformity in density be guaranteed in manufacture. No evidence exists to show how the consideration of different densities of gunpowder was first introduced ; whether it was caused by the actual observation that equal measures of different powders produced very different results in practice, or by the reflection that must have suggested itself, that if different amounts of the material be compressed into equal bulks, the effects of equal measures of such, whether taken by weight or measure, could not be equal. No delicate test was necessary to prove that if two grains of powder of equal size be taken, one of which is twice as dense as the other, that is, contains actually a much larger quantity of matter in it, and ignited in the open air, the denser will take a longer time in burning than the less dense. This must be the case, for the dense powder has not only a closer texture of grain which is more unfavourable to combustion, but contains actually a larger quantity of matter, bulk for bulk, to be consumed. Even the old mortar proof will show that a very dense and consequently heavy powder will give a less range than a less dense and consequently lighter one. We find, therefore, that for a very long period makers have been restricted to supplying powder of a certain *cube*, that is, powder which must weigh so much per cubic foot. This old gravimetric test has been in force for many years, and gives a rough and tolerably exact approximation of the density of the powder tested by it. In applying it the powder is suffered to run into a wooden box of exactly one cubic foot internal capacity, till the box is full to overflowing ; the excess is then struck off with a wooden rule, and the box with its contents weighed. The objection to this method of testing density is that the results are affected to a very considerable extent by

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the form of the grains of the powder, which pack more or less closely into the cube box accordingly; but as a rough and rapid way of trying the comparative densities of two specimens of the same class of powder, the cubing test is worthy of being retained. Slight variations of density, however, cannot be detected by it with certainty, variations such as do actually produce a very decided effect in the velocities imparted to rifle projectiles, and consequently in the pressures exerted on the guns at the moment of ignition.

The introduction of the densimeter has opened up a new field in the study of gunpowder. The actual use of the instrument will be fully explained hereafter, when the examination and proof of gunpowder are described; suffice it at present to state that the slightest differences in density can be at once detected by its use. The importance of this will be understood when it is further stated that by means of the various delicate electro-ballistic apparatuses now in use the exact effects of all varieties of powder can be accurately tested.

It would be beyond the scope of a sketch of manufacture and proof like the present to go thoroughly into the question of the effects that variations of density produce in gunpowder. It has not indeed been as yet sufficiently worked out. But a few examples will sufficiently show the great importance of the subject. To refer to the case of the old mortar proof, a reference may be given to the remark already made, that of two powders one may be compressed to such a high density as scarcely, with a small charge of two ounces, to project the shot from the mortar, while the same charge of the other may throw it 300 feet. But to come to more accurate statements. The present service R.L.G. powder is now made of a density about 1·67. Formerly, before the introduction of pebble powder, and in the absence of any store of powder which could be used without severely straining our larger guns, it was made of a density as high as 1·73. In both cases, of course, reference is made to powder tested during manufacture by means of the densimeter. The great bulk of the present store of that description of powder was supplied under the old cubing and mortar proof tests, and will consequently be found to vary very considerably in density, being as low in some cases as 1·60, and as high in others as 1·78. But new powder made under exactly the same conditions, and alike in all qualities but density, will give the most different results. Recently a long series of trials of 1 lb. charges of powder of the densities 1·67 and 1·73 have been made against each other in the 12-pr. M.L. rifled gun employed for proof at Waltham Abbey. The former gave an initial velocity averaging 50 feet greater than the latter.

To take an example of still greater consequence from the *Preliminary Report of the Committee on Explosives*, p. 10, charges of 70 lbs. fired from a 10-in. gun, with proof projectiles of 400 lbs., gave the following results :—

Pebble powder of density.	Velocity at 40 yds. from the muzzle.
1·84	1,288
1·78–60 lbs. 1·81–10 lbs.	1,424

The next point to be considered is how far the quality of non-fouling is affected by differences of density. As the question is one which relates almost exclusively to small arms, a better illustration cannot be given than that furnished by recent experiments in connexion with the powder supplied for use with the Martini-Henry rifle.

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The tendency of small-bore rifles to foul has long been well known. The Whitworth and Westley-Richards' rifles have invariably been found to foul unless when fired with special lubricating wads. It seems consequently to have been taken as an ascertained fact that all small bores will foul with all descriptions of powders, unless special means be devised to remove the fouling after each round. The fault, which was really one of the powder, has been transferred to the arms, and the whole of the efforts which have been made to overcome it, have been directed, not to modifications of the powder, but to modifications of the lubricant. Fouling is generally caused by the lubricated wad not acting during the first few rounds; indeed a single round may, and frequently does, foul a barrel. Now this failure of action may be due to one of two causes—either the wax wad may have become excessively hard, and consequently brittle, owing to being exposed to a very low temperature, or the action of the powder may be too rapid for it, and may, before properly expanding it, establish a rush of gas past it. Fouling caused by the first of these causes may occur with any arm, and can only be successfully overcome by the use of a better wad. Fouling arising from the latter cause is developed to a much greater degree in small-bore rifles, where the charge of powder is arranged in a long pencil-shaped cartridge, than in larger bores, and may be to a great extent, if not entirely, overcome by modifying the density of the powder used. For experience shows that the slower the action of the charge the less likelihood is there of fouling, the quicker powder being much more apt to set up a rush of gas past the wad before it is expanded. Slowness of action can of course be obtained at once by increase of density.

When the Martini-Henry rifle was introduced into the service it was found to shoot better with the No. 6 sporting powder of Messrs. Curtis and Harvey than with the R.F.G. of the service. The Royal Gunpowder Factory being then called on to supply a powder closely resembling the No. 6, a powder known as the M.H., made in all respects the same as regards ingredients, hardness, glaze, &c., as the No. 6, *but of a little less density*, was supplied for trial. The object of a reduction in density was to obtain a somewhat higher initial velocity, the question of fouling not having at that time excited any attention. The results given with this powder when fired against the No. 6 of Messrs. Curtis and Harvey were excellent. The shooting was better than that obtained with the contractor's powder. The trials, however, have been made with special regard to the arm rather than to the powder; and the rifles having been probably cleaned out frequently, no attention was drawn to the amount of fouling given by either powders. Subsequent trials, however, particularly those made when the weather was very cold, established the facts—

1st. That when not cleaned out both long and short chambered rifles foul very much at very low temperatures, both with the M.H. and the No. 6 powder.

2nd. That at a higher temperature they foul with the M.H. powder, but not with the Curtis and Harvey.

Disregarding the fouling in the first case, viz., at a very low temperature, which is mainly due to non-action of the wad, and which must therefore be met with modifications of it, the fact remained that at ordinary temperatures the contractor's powder did not foul, while the M.H. powder did. Attention was at once drawn to the differences in their densities. The former was found to have a density of about 1·73, the latter one of 1·62. This was the key to the whole difficulty, and as soon as the cause of the fault was known so soon was a remedy provided.

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A fresh powder (known as K) of a density between 1·67 and 1·69 was supplied, and the fouling of the arm was at once overcome.

The keeping qualities of powder, that is, its power to withstand disintegration from much shaking in transport, and to withstand the absorption of moisture, depend mainly on the density and hardness of the grains. The latter quality is affected to a considerable extent by the nature of the charcoal of which the powder is made. Obviously a very dense and very hard powder will form less dust, that is, will be less rubbed down in transport than a less dense and less hard one. The denser powder, too, will take a much higher polish than others, and will consequently have a smoother surface, a matter of great consequence if the prevention of dust in powder be sought. Experience proves that the small-arm powders, which are made of a much lower density than cannon powders, become sooner disintegrated and broken in the grain than the latter.

The higher density, therefore, we impart to powder the harder we make the grains, and the better polish we impart to them the more excellent will its keeping qualities be. But it must be constantly borne in mind that the density of a powder must be regulated more in accordance with its shooting than with its keeping qualities.

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CHAPTER IX.

THE MANUFACTURE OF GRAIN POWDER.

CONTENTS.—Two classes of powder now made: grain powders, and powders compressed in moulds.—The breaking up of press cake to form grain.—Importance of obtaining as large a per-centage of the right size of grain as possible.—Government manufacturers restricted to one size of grain.—The old L.G. and F.G. powders granulated together from the same press cake.—R.L.G. and R.F.G. powders now made from different materials.—Old method of "corning" clumsy and dangerous.—The new granulating machines of Congreve.—Description.—The rollers.—Screens or sieves.—How the different sized grains are separated.—Angles of the sloping screens.—Action of the machine.—Different sizes of grain which can be made in the machine.—Quantity of powder which may be granulated at one time.—Accidents in granulating houses.—Dangers of the process.

THE various descriptions of gunpowders now in actual use may be divided into two broad classes, viz. :—

I. Those made by breaking up pressed cakes of powder into grains or pieces of various sizes and shapes ; this class may be termed *grain powders ;* and,

II. Powders made by compressing *powder meal* from the breaking-down machine, or *grain powders* as above defined, in moulds. To this latter class belong the various descriptions of pellet and prismatic powders.

In the following chapter we propose to discuss the manufacture of the former class of powders.

The stage of manufacture at which we have arrived in the preceding pages is this—we have at our disposal a quantity of powder pressed into flat cakes of nearly uniform density. Our object is now to convert this press cake (already broken up into pieces about the size of a man's hand) into the particular size of grain required. And the means employed to break up the press cake must be so arranged as to crush it up as nearly as possible into the size or sizes of grain wanted, without reducing much of it to dust ; in other words, arrangements must be made to obtain as large a per-centage of grain from the cake operated on as possible. Crushing up the cake would be a very simple matter if crushing only was the object ; but a machine which crushes it so effectually as to give the manufacturer only 50 per cent. of the size of grain he wishes, and which therefore compels him to send back one half of the powder to the incorporating mills or press house,* would cause him a very considerable loss in time and wages. These remarks apply much more forcibly to the case of a Government factory, where, as a rule, only one size of grain is made from the press cake, viz., the particular size fixed on as the best for the service cannon or small-arm

* It is necessary to re-work in the incorporating mills any small grains or dust which come from the granulating or dusting houses. Private makers who have a smaller proportion of waste, owing to their being able to sell many different sizes of powder, sometimes merely press the dust without re-working it.

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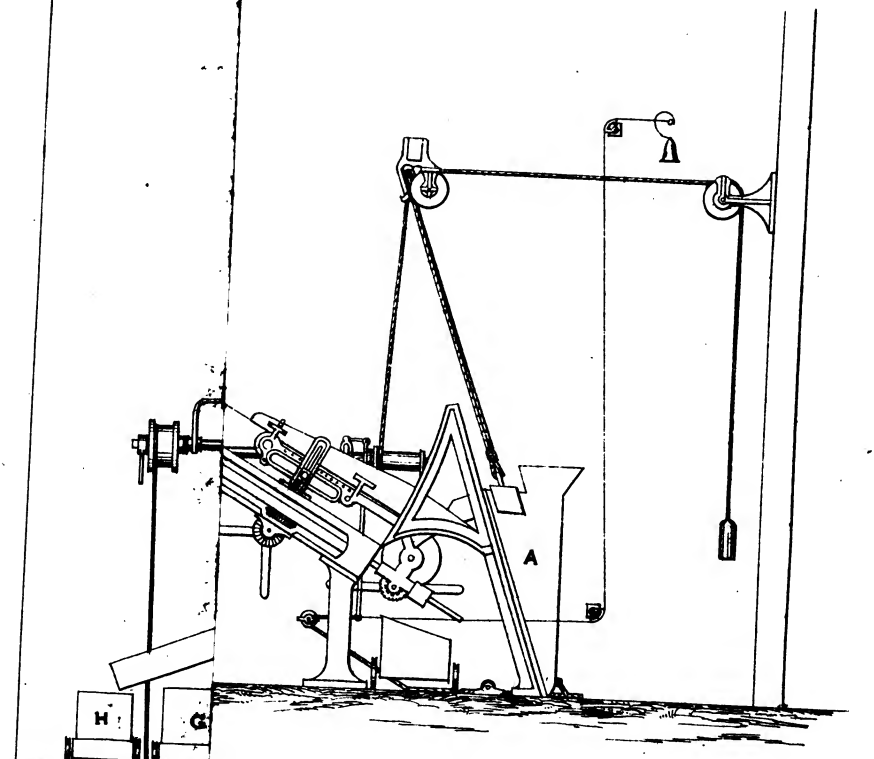
Plate 18.



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powder, than to a private manufactory of sporting and blasting powders, where many different sizes of grains, all of which are saleable, can be made at one time. In the case of the latter, the crushed-up press cake is sifted through a succession of sieves, till all sizes of grains, except the finest dust, are separated; and the different sizes are numbered, and after being properly glazed and finished sent to market.

But the manufacture at a Government factory is totally different. Speaking broadly, there are only two classes of powder ever made in it, the cannon and the small-arm, the latter made with dogwood charcoal. It is therefore of the greatest consequence that the largest possible per-centage of grain should be obtained from the press cake which undergoes granulation.

Not many years ago the cannon powder of the service was that known as L.G., the size of grain being between $\frac{1}{8}$ and $\frac{1}{16}$ inch, a very small grain comparatively. The small-arm powder was the F.G. size, from $\frac{1}{16}$ to $\frac{1}{32}$. This powder was made with alder and willow charcoal, and could therefore be made from the same press cake as the L.G., and as it was the next size below it, at the same time. The smaller the size of grain the larger will be the per-centage of it obtained from granulated press cake; hence with the above sizes of powder any of the older and ruder appliances for effecting granulation gave good per-centages of grain, and there was consequently little necessity for improving them, except as regards safety of working. But the L.G. has been replaced by R.L.G., a much larger size of grain ($\frac{1}{4}$ to $\frac{1}{8}$ inch), and small-arm powder is now made of dogwood charcoal, and, therefore, altogether apart from the former, so that at present any fragments of press cake which pass through the 8-mesh, are of no use except for re-working. And recent experiments have conclusively proved that R.L.G. is too small a grain for employment in large charges, and that a much larger size still (known as "pebble"), from $\frac{3}{8}$ to $\frac{1}{2}$ inch, is required.

The old method of graining powder was by the *corning machine*. This consisted of a large rectangular frame of wood hung to the ceiling by ropes, and having a crank underneath by which it could be oscillated round. On the frame were placed a number of sieves having double bottoms of parchment, the upper having holes large enough to admit the size of grain wanted, and the lower having much smaller holes to admit the passage of dust. In each sieve was placed a round disc or "cheese" of *lignum vitæ*. A quantity of press cake having been put into each sieve, and the machine started, the *lignum vitæ* discs dashing about in the sieves soon reduced the cake to fragments, which passed through the upper sieve and were retained on the lower, while the dust passed through on to the floor, from whence it was shovelled up after the operation was over. These machines are both clumsy and dangerous. The last one in use at Waltham Abbey was destroyed by the fatal explosion in 1843, since which time none but the new granulating machines of Congreve have been employed. These machines are found to be perfectly safe, and to give very good results as regards per-centage of grain obtained from them. This is particularly the case with the small-grained powder used with small arms, and also to a somewhat less extent with the R.L.G. Larger powders than the latter have hitherto been made by throwing the press cake on a table and breaking it up by hand with mallets, but there is little doubt that arrangements and alterations might be made in the machines, so as to enable them to granulate powders of any size of grain.

The granulation is effected by passing the press cake between revolving toothed rollers of gun metal. The newest machine at the

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Royal Gunpowder Factory (see Plates 18 and 19) contains four pairs of such rollers, arranged in a slanting direction, one above the other. These rollers are set in the two strong side frames of gun metal which form the framework of the machine. Each pair is adjusted at the proper distance apart by set screws; but the back roller of each pair works in a sliding bearing which is kept up against the bearing of the other roller by a weighted lever, so as to admit of the rollers opening out and admitting an excess of material to pass through without injury to the machine. The two upper pairs of rollers have coarser teeth than the lower pairs. Slanting rectangular sieves or screens are placed from underneath each of the three upper pairs of rollers to the top of the next, to convey any fragments which escape proper crushing in one pair into the teeth of the next pair. Underneath the whole is a long rectangular frame carrying two long screens to separate the proper size of powder, and a board underneath to receive the dust and carry it down into a tub placed to receive it. Both the short screens and the long frame are attached to the framework of the machine by strips of lancewood, and receive a vibratory motion by means of a polygonal wheel, which works against a circular wheel running loose on an axle fixed on the screen frames.

The press cake is placed in a hopper at the back of the machine, and carried up by means of an endless band, just as described in the breaking-down machine.

The first pair of rollers have pyramidal teeth $\frac{1}{4}$ in. high; the second pair, similar teeth $\frac{1}{8}$ in. high; the two lower pairs have chisel-shaped teeth, formed by cutting longitudinal V-shaped grooves and circumferential rectangular ones. The two lower pairs are replaced by smooth ones when R.F.G. gunpowder has to be granulated. The arrangement and sizes of mesh of the screens may be easily remembered, if the fact be borne in mind that only *one* size of powder is required, and the size is defined by the fact that it must pass through one mesh and not pass through another. The short screens, therefore, between the rollers are covered with the size of mesh through which the grain must pass, to allow all fragments of the right size to fall through, but which carry-on the pieces which are too large to the next pair. The upper screen of the long frame underneath is covered with the same wire; the lower one with the size of mesh wire on which the grain required must be retained.

Attention must be paid to the angles at which the different screens are placed; this varies in different machines, and the proper inclination can only be ascertained by experiment.

The diagram (page 59) will explain better than words the arrangement of the screens and rollers, as used in the newest machine at Waltham Abbey. The three short screens between the rollers and the upper one of the long screens underneath are all covered with the largest size of mesh, the lower screen with the smaller size. These screens will of course require to be changed for each different size of powder that is being made. Thus if R.L.G. is being granulated—a powder which must pass a sieve of four meshes to the inch and be retained on one of eight—the short screens and upper long one would be covered with four mesh, the lower with eight: if R.F.G., which must pass a 12-mesh and be retained on a 20, the short screen and upper long one must be of 12 mesh, the lower long one of 20. Duplicate sets of screens are kept ready for use with all the Waltham Abbey machines.

The general action of the machine will be understood from an inspection of the plates and woodcut.

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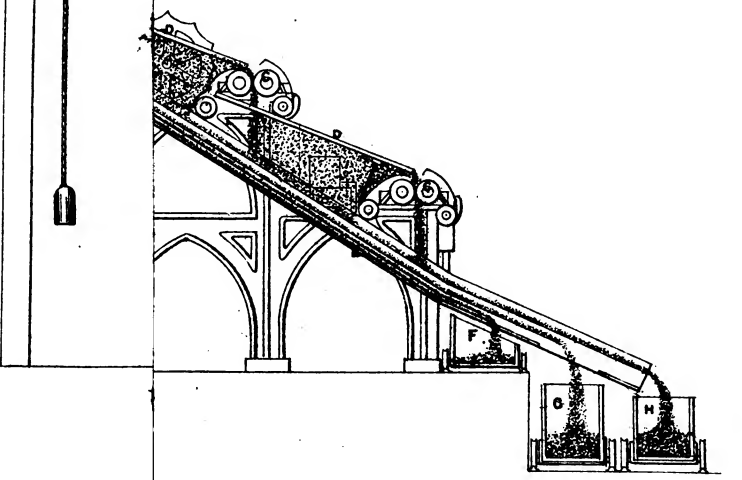
Plate 19.



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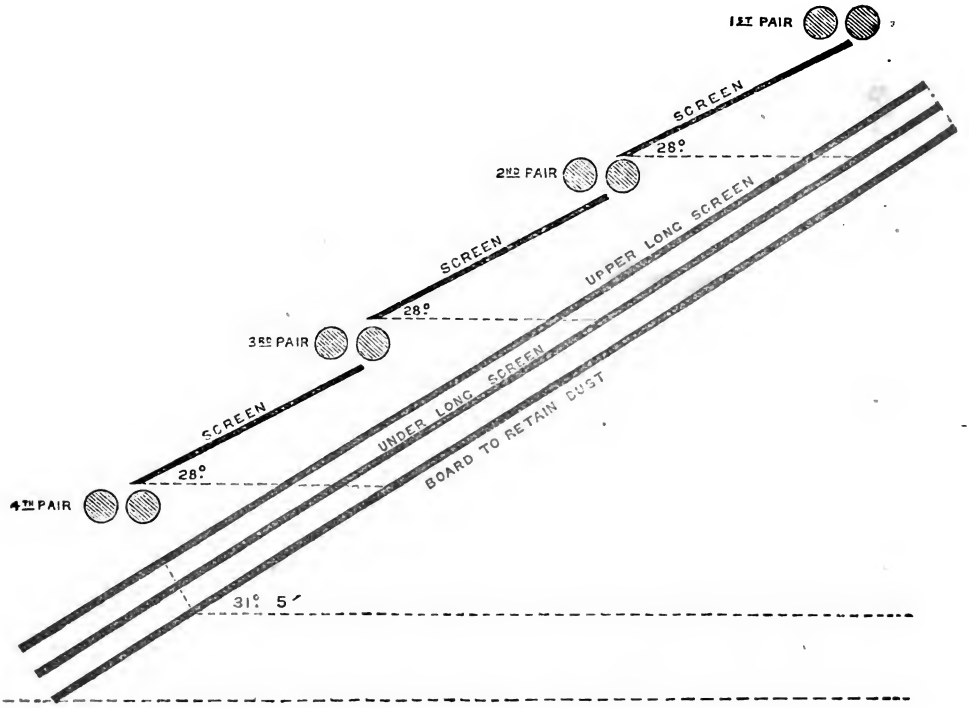
About seven barrels (700 lbs.) of press-cake broken into irregular pieces is put into the hopper, which is slowly raised by the action of the machine as the cake is worked up. The endless band of canvas having strips of leather sewed on to it to catch the cake, works out of the hopper



carrying a stratum of press cake up to the top pair of rollers. The band passes under a scraper which prevents too much cake being carried up at once. The cake falls between the first pair of rollers, which work at a speed of about 30 revolutions per minute, and is immediately crushed up into granular fragments which fall on the first short screen. All the screens work with a quick vibrating motion. The whole of the grains, except the fragments which are too large, fall through this screen directly on to the surface of the upper long screen underneath, and fall through it likewise to the second, which permits the dust and minuter particles to fall through on to the sloping board underneath, down which they slide into the tub placed to receive them, but which retains the proper size of grain, which in turn rolls down it into another receptacle at the bottom. The larger pieces which escaped proper crushing in the first pair of rollers, are shaken down by the first short screen into the second pair, to undergo the same process as at first, and so on with the third and fourth pairs of rollers. Some fragments of too large a size will escape all the rollers, and consequently require a third box to receive them in front of the other two placed to receive the dust and grain respectively. These pieces, technically termed "chucks," require to be passed through the machine again. When the hopper has reached the limit of its travel upwards, and all the cake has fallen out on to the band and been conveyed up to the machine, a clutch is relieved which stops the upward travel of the hopper, and a bell is rung in the watch house where the

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workmen remain during the time the machine is working. The machine being self-supplying requires no watching when working. As soon as the bell rings the workmen re-enter the house and place the grain and dust in tubs ready for transmission, the former to the dusting houses, the latter to the mills for re-working.

The largest size of grain which has been hitherto made in the granulating machine is the service R.L.G., formerly called A 4. This powder must pass through a sieve of four meshes and be retained on one of eight. As previously mentioned, the per-centage of this size of grain obtained from a quantity of press cake is not so large as it should be. Under these circumstances it seems to have been taken for granted that to attempt to manufacture a still larger size of grain would be injudicious. But there is very little doubt that rollers may be so constructed to cut grains or fragments of almost any size or shape out of press cake. This question has recently assumed considerable importance from the fact that the Committee on Explosives under the presidency of Col. Younghusband, R.A., F.R.S., superintendent of the Royal Gunpowder Factory, has reported favourably on a powder (known as pebble powder) made of press cake broken up by hand into pieces of about $\frac{1}{2}$ inch square. A powder of this class, if made of a high and uniform density, gives such excellent results as regards initial velocity combined with reduction of pressure in the gun, that its provisional adoption has been recommended. The French have also obtained good results with powder of the same class. As such powders will probably become service powders, it is of the highest consequence that means should be devised to obtain as large a quantity of them from the press cake as possible. In France all powders of this class have been made by throwing the cake on wooden tables, and breaking it up by hand with wooden mallets armed on the face with bronze points. The experimental powders made for the committee at Waltham Abbey have been made in a similar fashion, but a new description of roller for the granulating machine will be tried shortly, by means of which there is reason to hope *pebble powder* will be as easy of manufacture as any of the older and better known kinds. If not, ordinary press cake may be easily cut with hinged bronze knives into fragments of the size and shape required.

The quantity of gunpowder which may be granulated at one time in one building is limited by the Act of Parliament to 12 cwt., and not more than twice the quantity is permitted to be in the house at one time. The remarks made under the head of press houses, on the inutility of fixing a limit to the powder which may be in a house, without defining the distance such house must be from other buildings, apply with equal force to the case of granulating houses.

To judge from the large proportion of accidents which take place in granulating houses, or "corning-houses," as they are generally termed, from the old process formerly carried on in them, the process would appear to be specially dangerous. Of the twenty-nine great explosions which happened in powder works between May 1858 and June 1870 (putting the minor explosions of incorporating mills out of the question), no fewer than eleven originated in corning-houses, an average of nearly one per annum, a very large average and a very serious one, when the destruction of life and property is taken into account. At the Battle works in 1860 a corning-house exploded, killing one man; the same year another exploded at the Melfort works in Argyleshire, killing six; in 1863 at the Ewell works, in Surrey, another followed, exploding also a glazing house, and killing three; and in December the same year the great explosion at the Kames works in Argyleshire took place,

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which originated in a granulating house, and in which seven of the workmen were killed and eight others burnt and injured. This was perhaps one of the worst explosions in a powder factory ever recorded. The flame was communicated from the granulating house in succession to a press-house distant 150 yards, to a glazing-house distant 100 yards from the press-house, then to a dusting-house 200 yards distant from the press house, then to a double press-house about 200 yards distant from the last, and finally to a glazing-house at the same distance. Some of these exploded almost simultaneously with the granulating-house, but from the others the workmen managed to get clear before the explosion, escaping with a few burns and wounds from falling timbers. The other explosions of granulating houses were, one at the Faversham works in 1864, in which two men were killed; an old-fashioned corning-house at the Roslin works in 1866, one man killed; a granulating house at the Melfort works in the same year, in which three men lost their lives; two others in December 1867, one at the Blackbeck works near Ambleside, killing three of the workmen, and the other at Faversham, which exploded also a double press-house and a charge magazine, and destroyed the lives of eleven people; another at the Lowood works in November 1868, by which four men were killed; and the last at Hounslow in December 1869; on which occasion the lives of three workmen were destroyed. The total loss of life in these explosions was, therefore, forty-four.

It is difficult to account for the fatality which accompanies granulating houses. At the Royal Gunpowder Factory the operation is not considered to be any more dangerous than any of the other processes; but the statistics quoted above show beyond doubt that it must be specially dangerous to private manufacturers. The probable explanation appears to be that if there has been any negligence anywhere in keeping fragments of foreign matter, whether sand or grit from the ingredients, or pieces of stone or iron, bolts or nuts from the machinery, from the powder as it progresses through the various stages of manufacture—the granulating house, in which the powder undergoes more crushing and grinding than it does anywhere else, and where there are a number of metal axles and bearings at work, is the place where such negligence will most surely tell. The bearings of powder machinery may certainly become so hot as to inflame the powder dust with which they are constantly in contact, but this can only happen through the grossest negligence. And if all foreign substances can be certainly excluded from the powder in all stages, there ought to be little risk of accident in carrying on the manufacture. But this is not so easy of attainment as it may appear to be. For instance, a fragment of metal may be broken off some machine and fall into the powder, or a gust of wind may carry in a few gritty particles through the doorway of a powder house, which may be swept up with the dust and so escape the most vigilant attention. It is, perhaps, needless to state that every possible precaution which can be devised to prevent any accident of the kind is in constant force at Waltham Abbey.

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CHAPTER X.

INFLUENCE OF THE SIZE AND SHAPE OF THE GRAIN ON THE QUALITIES OF POWDER.

CONTENTS.—An important question.—Caution as to generalization in powder experiments.—Results obtained with small charges of powder frequently reversed with large ones.—The combustion of grains of gunpowder.—Partial combustion of large charges of powder.—Equal charges of different descriptions of gunpowder take equal times to burn.—Powder compared together as to grains must be of the same density.—Spherical and flat grains of gunpowder.—Large and small grains.—Very different action of powder burnt in the open air and under pressure in a gun.—If uniformity of action be desired both the size and shape of grains must be uniform.—Ignition of a charge as distinct from its combustion.—Generally speaking a large-grained charge slower in action than a small-grained one.—A great deal depends on the form of the charge and the point of ignition.—Recent experiment at Waltham Abbey on size of grain.—Curious results.

As it is important, in tracing the course of manufacture, to bear clearly in mind the object with which every step is undertaken, we must now consider, before going further, the question of the *effects which differences in size and shape of the grains exercise on the qualities of gunpowder.* The inquiry is a most important one. It is impossible to form a clear idea of the present state of the gunpowder question, or of the end for which the recent experiments on this subject have been undertaken, if these two points (one of which has been already discussed) be not understood, viz., the effects which difference of density and differences in size and shape of grain have on the qualities of powder. The whole course of present manufacture is based on considerations of these two all-important points.

Before proceeding to the subject of this chapter a caution must be given as to deduction and generalization in powder experiments. Nothing is more common than to find hasty conclusions, drawn from experiments made on a small scale, asserted as universally true. The results obtained with small charges of powder are held as being equally applicable to larger ones; and the phenomena observed in burning powder in the open air or *in vacuo* are, perhaps naturally, supposed to be exactly identical with those which take place when the powder is burnt under enormous pressure. Generalization is especially unsafe in all experiments connected with powder, and most of all in this very matter of the consideration of differences of size and shape of grains; for experience had proved beyond risk of doubt that results which are obtained when working with small charges frequently are reversed when the experiments are made on a larger scale. In the following chapter, therefore, care has been taken to assert nothing of which absolute proof is not forthcoming, and in matters which are incapable of such, to preserve as wide a distinction as possible between what *probably* does and what can be proved *actually* does happen.

The question of the ignition and combustion of a charge of powder must first be considered. There can be no doubt that, though a charge of powder when fired explodes apparently instantaneously, the combustion is gradual, and that the flame is communicated from one grain

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to another, each grain burning in concentric layers till it is consumed, until the whole is burnt. In fact the combustion of the grains of powder, though instantaneous, is not simultaneous. It has often been observed that when firing with large charges, the part of the charge which is furthest from the vent is blown out of the gun unconsumed, and may be seen on the ground under the muzzle of the gun. This, of course, shows that the flame did not reach this part of the charge soon enough to consume it, that the explosion of the back end of the charge was complete, and exercised its propelling effect, before the front part of the charge could be reached by the flame.* There can be no doubt that equal charges of different powders take different times to burn, and consequently exercise more or less sudden strain on the gun in which they are fired. And from what has been said it is evident that the rate of burning of a charge of powder will be affected by the rate of burning of each of its constituent parts.

In all considerations of this subject it must be distinctly understood, that whenever any statements are made of the rates of burning of different powders, the powders are supposed to be of *exactly the same density.* The reader will be prepared, after a perusal of the remarks on differences in density in a preceding chapter, to acknowledge that unless powders are ascertained to be of uniform density, there is no use instituting a comparison between their other qualities. This must be the starting point in all powder investigations.

Now it admits of very easy proof that two grains of equal size, similar shape, but unequal density, will take different times to burn. This can be seen at once, for if two cubes or two cylindrical pellets of equal size, the one of a very low the other of a high density, be burnt on a glass plate, the less dense one will be entirely consumed before the denser one has finished burning.

In like manner, the *same quantity* of powder meal, if made into two grains of very *different shape* though of *equal density*, will take different times to burn. It is with this latter question that we are more immediately concerned at present.

Obviously, when a grain of powder is ignited it takes fire over all the surface, and continues burning towards the centre in concentric layers till it is entirely consumed. The larger, therefore, the surface exposed the speedier will be the combustion of the grain of powder. A sphere being the smallest form in which matter can be placed, it follows that a certain quantity of powder-meal compressed into a spherical form will take a longer time to burn than the same quantity made up into the form of a flat scale. In other words, the more nearly powder grains approach a spherical form the longer time will they take in burning; the more elongated, flat, and angular they are, the quicker will they burn. So much for the *shape* of the grains. As regards their *size*, it is perhaps needless to point out that a large grain of powder takes longer time to burn than a smaller one, there being, of course, a larger quantity of material to be consumed. If other things therefore are equal, a charge made up of large grains of powder may be expected to take a longer time to burn than one made up of smaller ones.

It is very easy to show by actual experiment that a round grain will take longer to burn in the open air than a flat elongated one containing the same quantity of matter, and that a large grain takes longer to burn than a small one. The combustion of single grains of considerable size

* It is a remarkable fact that when firing very large grain powders, such as "pellet" and "pebble," the unconsumed fragments found lying in front of the muzzle are found to be of a much higher density than before firing.

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and density is so gradual when burnt in the open air, that the times can be watched and compared. But it must be remembered that the combustion of such grains in the bore of a gun, where they are subjected to enormous pressure, is a very different matter altogether. In the former case the products of combustion—the gases evolved—continue, as they escape into the air, to abstract the heat generated by the burning gunpowder so rapidly, that it cannot accumulate to an extent sufficient to cause an explosion at all. In the latter, however, the pressure to which the burning powder is subjected causes the gases to be confined on the burning surface, prevents any abstraction of heat, and produces a far more rapid and violent decomposition. If this be the case, then it may be asked, why base conclusions as to what goes on within a gun upon observations made confessedly under very different conditions? All that can be said is, that though the combustion of grains of powder in a gun is far more thorough, rapid, and violent than in the open air, yet there is no reason to doubt that the same comparative effects may be expected from the grains, whether burnt slowly or quickly; that though the actual rate of combustion is in all cases infinitely more rapid, yet the round grains will take longer time to burn than the flat ones, the larger ones than the smaller.

This being admitted, it follows that if uniformity of action be required in charges of gunpowder, the constituent grains of such charges must be of the *same shape* and of the *same size*. No powder can be expected to give regular results which is not uniform in these points.

The foregoing considerations as to shape and size of grains relate entirely to the question of the rate of *combustion* of a charge of gunpowder, not to the rate of its *ignition*. The distinction between these two terms must be here explained, and must be carefully borne in mind in all investigations relating to the comparative slowness or quickness of different descriptions of gunpowder. The former term, *combustion*, is intended to apply only to the burning of the individual grains; the latter, *ignition*, to the kindling of the whole charge. Thus a powder may possess a slow rate of combustion and yet a high rate of ignition, or—the converse of the case—a high rate of combustion with a slow rate of ignition. To take an example as the best way of explaining our meaning—a large grained powder it has been said above may be expected to burn more slowly than a small grained one, for the obvious reason that large grains take longer time to consume than small ones. But a cartridge made up of large grains affords much larger interstices between its grains for the passage of the flame than one made up of small grains tightly packed together would, and would therefore be much more rapidly *ignited* throughout than the latter. It does not therefore follow as a matter of certainty that, *under all circumstances*, a charge of large grains of powder will act more slowly than an equal charge of the same powder in the shape of very small grains. The flame may *set up* the front of the cartridge of small grains so much, and take so long in permeating through it, that the action may under certain circumstances be less severe than the action of a charge of large grains.

Speaking broadly, however, the rule that a large-grained powder is slower in action than a smaller one is generally true within certain limits. For if the size of grains be either very much increased or very much diminished, the slowness or quickness of combustion of the individual grains thereby obtained will be more than balanced by the increased or diminished rate of ignition. Probably a great deal depends on the length and shape of the charge in which the powder is made and the point at which it is ignited.

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Some very curious results have recently been obtained at Waltham Abbey when comparing the initial velocities given by different sizes of grain. It had always been found there that R.F.G. powder, when separated by sifting into the various sizes of which it is composed, gives a higher velocity to a rifle bullet as the size of the grain diminishes. In like manner, R.L.G. when sifted into different sizes gives a higher velocity with a 1 lb. charge and 12 lb. shot, as the size of the grain is reduced. It was therefore almost becoming an accepted fact that the rule broadly stated above was true, viz., that reduction of size of grain gave increase of velocity. An alteration of charge and projectile completely reversed the results. The following short tables are most instructive.

12-pr. M.L. Rifled Gun.

EXPERIMENT I.

Powder R.L.G. sifted.

Charge.	Shot.	Size of Grain.	Mean observed Velocity at 105 feet.
1 lb.	12 lb.	4 to 6	976
„	„	6 to 8	1,001
„	„	pass 8	1,015

Velocities *increase* as grains diminish.

EXPERIMENT II.

Powder R.L.G. sifted.

Charge.	Shot.	Size of Grain.	Mean observed Velocity at 105 feet.
1¾ lb.	9 lb.	4 to 6	1,410
„	„	6 to 8	1,369
„	„	pass 8	1,292

Velocities *decrease* as grains diminish.

If the latter experiments had been still further extended with a larger size of grain the result would have been again reversed. The following are the results of a later experiment.

EXPERIMENT III.

Powder R.L.G. sifted.

Charge.	Shot.	Size of Grain.	Mean observed Velocity.
1¾ lb.	9 lb.	3 to 4	1430·7
„	„	4 to 6	1454·1

Velocities *increase* as grains diminish.

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These experiments afford a practical comment on the statement as to the danger of generalization in powder experiments formerly made, and prove that it is only by actual experiment with a particular gun, a certain charge, and a certain projectile, that the action of a particular description of powder in that gun can be ascertained.

Two later experiments with small arms are appended, showing the increase of velocity obtained by diminishing the size of grain. These are merely given as illustrations of the subject, not as in any way exhausting it.

Experiment IV.

Special R.F.G. Powder. Arm, Snider-Enfield.
Charge, 70 grs.

Size of Powder.	No. of Grains in 10 grains weight.	Mean of Velocities at 105 ft. from muzzle.
12 to 16	326	1,039
16 to 20	626	1,088
20 to 24	1,072	1,111

Experiment V.

Special R.F.G. Powder. Arm, Henry.
Charge, 85 grs.

Size of Powder.	Mean observed Velocity at 105 feet from muzzle.
12 to 16	1245·0
14 to 20	1256·

The same experiment repeated with a 90 gr. charge gave the following results:—

Size of Powder.	Mean observed Velocity at 105 feet from muzzle.
12 to 16	1287·0
14 to 20	1298·7

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CHAPTER XI.

DUSTING, GLAZING, DRYING, AND "FINISHING."

CONTENTS.—Granulated powder contains much dust, and therefore unfit for immediate use.—How powder is freed from dust.—Different descriptions of powder require different treatment.—The horizontal reel: description; use of horizontal reels.—Slope reels: description; use.—Various dustings, &c., which R.L.G. and R.F.G. undergo.—The glazing barrels or "churns."—Description and use.—Graphite used under certain circumstances.—"Sweating" of powder in the glazing process.—Second and third dustings.—The steam stove.—Gloom stoves.—Description of stoves in use at Waltham Abbey.—Management of the stove.—Probable effect of glazing on powder.—Value of glazing as enabling the powder to stand damp or transport.—Quantities of powder that may be dusted, glazed, or stoved in one house at one time.—Accidents in such houses.

THE granulated powder as it comes from the machine contains amongst it a large quantity of dust. This is formed by the crushing action of the granulating machine, and must of course pass through the various sieves and screens with which the machine is provided along with the grain. The grain itself is not in a condition to be made use of as powder, being rough and porous on the surface and very angular in shape; and, moreover, the presence of a large quantity of fine dust amongst it would render it not only most inconvenient to handle in magazines or elsewhere, but would also render it more liable to absorb moisture and to deteriorate. A rough unpolished angular grain would also very speedily rub down into dust, if subjected to much shaking in transport. The object of the gunpowder-maker is therefore first of all to free the granulated powder (in this stage termed "*foul grain*") from all traces of dust, and secondly, to polish or give a surface to the grains themselves, to enable them to bear a great deal of friction together without deterioration.

Powder is freed from dust by placing it in revolving "reels" covered with cloth or wire mesh of various degrees of fineness, through which the dust escapes. It is "glazed" by causing the grains to rub against each other in revolving wooden barrels or churns.

Now the extent to which the operations of dusting and glazing can be carried, and the nature of the appliances used, depend entirely on the density, hardness, and size of grain of the powder operated on.

It is clear that a large-grained dense hard powder will bear a great deal of knocking about in the reels without becoming disintegrated and forming fresh dust; and will moreover bear a great deal of friction in the glazing barrels, acquiring speedily a high degree of polish. But the case is quite different if a small-grained soft powder of low density be operated on. In the latter case the dusting must be carefully conducted, or the process will develope as much fresh dust, as it removes, and the amount of friction the grains will bear in glazing without simply rubbing away to nothing must be likewise carefully regulated.

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It is found in practice that powder may be divided into two classes, each of which requires different treatment in dusting and glazing, viz., the *cannon powder* of all classes made with alder or willow charcoal, and the *small-arm powder of all classes* made with dogwood charcoal.

The former class of powder is not only pressed to a higher density, but is made of a larger size of grain; the latter generally is of lower density and much smaller size.

There are two classes of reels in use, the *horizontal* and the *slope*. A horizontal reel (see Plate 20) consists of a cylindrical skeleton of wooden hoops supported on a shaft by radial arms, the skeleton being covered with canvas or wire cloth of various sizes of mesh, to suit the size of grain to be dusted. The reels are made in halves, for convenience of repair and re-covering. The shaft is of iron covered with wood; the radial arms are of gun metal. Each reel is 8 feet long by 2 feet 6 inches in diameter. The ends are formed of two stout discs of wood screwed upon the shaft. One end can be unscrewed and drawn back. The bearing of the reel shaft next this moveable end is fixed in a block which can be lowered if necessary, so as to put the reel for the time being on a slope. In the middle of the reel is a square opening closed with a wooden door, through which the powder is placed in the reel, being run in through a hopper at the top of the panelled wood casing in which the reel is placed to confine the dust which escapes from it.

Horizontal reels are intended to receive a quantity of powder for a certain length of time, and to revolve with it, shaking it against the reel covering, and thus forcing the dust through the wire or cloth of which the covering is composed. Such reels are generally covered with stout cloth of 24 meshes to the inch, but may be used with all kinds of covering, provided the powder to be dusted in them is not of such a soft or dusty character as speedily to choke up the interstices of the reel cloth, and so defeat the object for which the reel is used. They are driven by water power, and revolve at a speed of about 40 revolutions a minute. When a reel has run the required time with a charge of powder the driving wheel is made to revolve very slowly, the end of the reel is lowered by means of a rope and lever (*see* plate), and the moveable end of the reel is unscrewed and drawn back. As the reel slowly revolves the powder runs out of it into a hopper placed to receive it and conduct it into the barrels.

Slope reels (see Plate 21) are not intended to retain the powder at all, but only to extract a certain portion of dust from it as it runs through them from end to end, which only occupies a few minutes time. They resemble the horizontal reels in general construction, but are made of a smaller diameter, only 1 ft. 8 in., and differ from them in these two important particulars—first, that they have no ends, being open at each extremity; and, second, that the shaft axis of the reel is set at a permanent slope of $1\frac{1}{8}$ inch per foot. From the nature of the work they have to perform they are generally covered with wire cloth of very fine mesh or Cyprus silk. Each reel is provided with a feeding hopper at its upper end, attached to which is a loose spout for guiding the powder into the reel. This spout receives a constant series of knocks from three ribs fixed on the shaft of the reel, and is thus kept in perpetual vibration, which effectually keeps it clear and prevents the fine-grain powder from choking it. Slope reels revolve generally a little slower than horizontal ones, making about 38 revolutions a minute.

Different powders take different lengths of time to be freed from dust, and require different descriptions of reel coverings. It is impossible, therefore, to lay down exact rules on such matters, and it would be tedious to go over all the particulars of the numerous dustings that all

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HORIZONTAL REEL.

SECTION.

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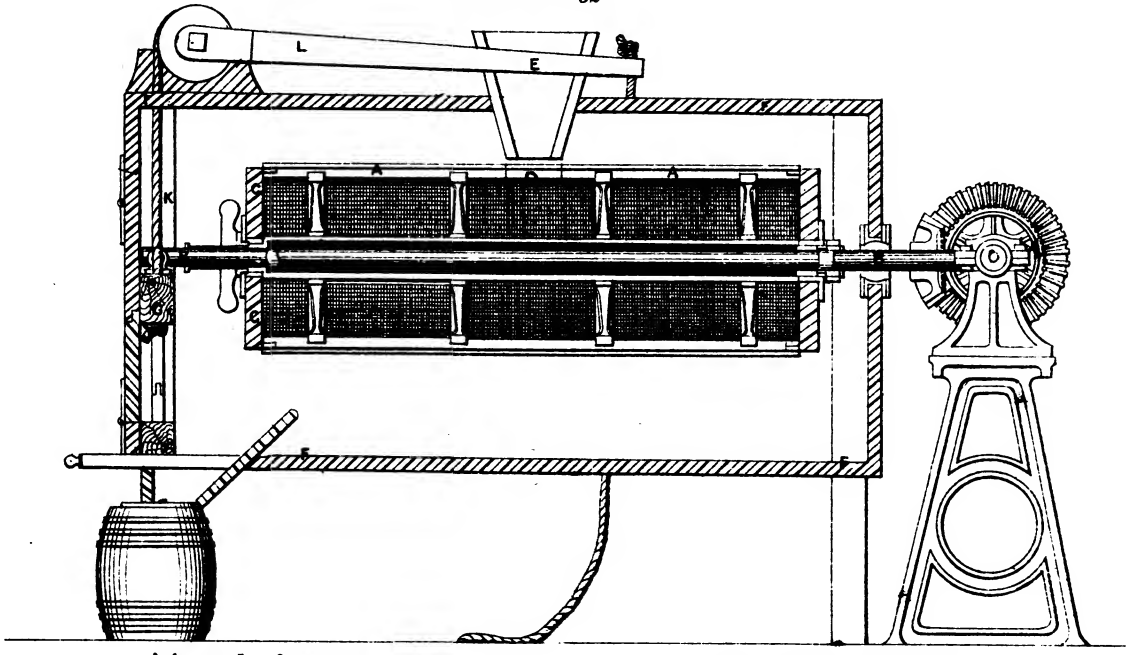

A A ... *reel Covering*

B ..... *Shaft*

C C .... *Moveable End*

D ..... *Opening for loading*

E .... *Hopper for d.º*

F F ... *Reel Case*

G .. *Block carrying the bearing of the lower End which can be raised or lowered by means of the rope* (K) *& Lever* (I)

Face P. 68.

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SLOPE REEL

SECTION

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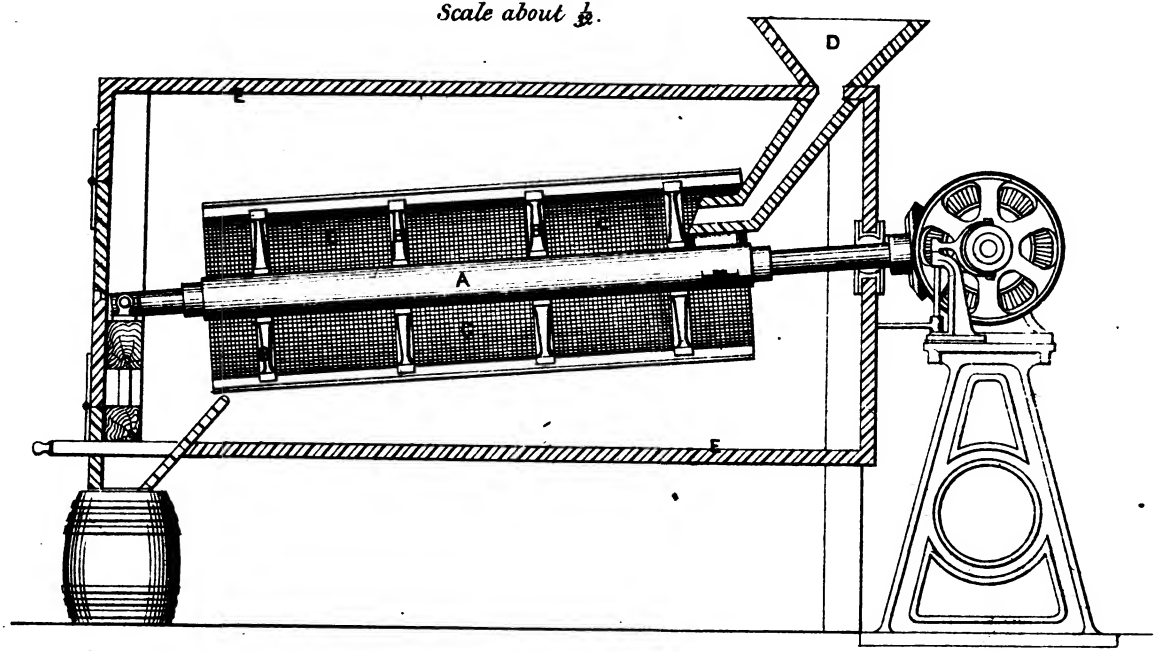

A..... *Shaft*
B B.. *Radial Arms*
C C *Reel Covering*
D..... *Hopper*
E E.... *Reel Case*

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kinds of powders undergo. A brief description, however, is subjoined of the processes which would be followed *generally* with cannon and small-arm (dogwood) powders. The following table shows what the R.L.G. and R.F.G. powders actually undergo, after leaving the granulating machine, and before they are ready for use.

TABLE A.

—	R.L.G.	R.F.G.
1st Dusting -	In a horizontal reel covered with 24-mesh canvas, making 40 revolutions a minute for half an hour.	Run through a slope reel covered with 24-mesh canvas, making about 40 revolutions a minute.
Glazing -	In wooden barrels making 34 revolutions a minute for 40 minutes, with ½ oz. graphite per 100 lbs.	In wooden barrels making 34 revolutions a minute for 5½ hours.
2nd Dusting -	In a horizontal reel covered with 24-mesh canvas, making 40 revolutions a minute for half an hour.	Run through a slope reel covered with 28-mesh canvas, making about 40 revolutions a minute.
Stoving -	Same for both.	
3rd Dusting or "Finishing."	Not required - - -	In a horizontal reel covered with 28-mesh canvass, making about 45 revolutions a minute for 2½ hours.

Dusting and Glazing of Powder of the R.L.G. Class.

The R.L.G. as it comes from the granulating machine in the state of *foul grain* is placed in a horizontal reel covered with 24-mesh canvas, and run for half-an-hour at a speed of 40 revolutions a minute. The grain of the powder being of a large size (between a four and eight mesh), and of firm consistency, admits of a comparatively open-meshed reel-covering being used, and of the process being continued as long as required without risk of injury to the grain. The powder can therefore be rendered perfectly free from dust, and comes out of the reel as clear as finished powder would be. The grain though it is smoother somewhat in surface than when in the state of *foul grain*, has not of course any glaze communicated to it from its half-hour's rubbing in the reels. It is therefore transferred to the glazing barrels, a description of which must here be given. They consist of large very strong wooden barrels supported on an iron shaft which runs through their centre. The barrels, two of which are generally placed in line on one shaft, a set consisting of four, are made of oak, and are five feet long, and two feet six inches in diameter in the middle; the shaft is cased with wood where it passes through the barrels. The arrangement and construction of the barrels are shown in the illustration (Plate 22), and require little explanation. Each barrel is provided with a small square

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door for charging and uncharging. They are capable of holding 400 lbs. each, make about 40 revolutions a minute, and are driven by water power. The barrels are found to be peculiarly well adapted for the purpose for which they are used, owing to their shape. Formerly wooden cylinders with straight sides were in use, but it was found that the different sizes of grain had a tendency to separate in them, the larger grain occupying one part of the cylinder as it revolved, the smaller another, so that all the contents of the cylinder did not receive an equal amount of polishing. But in the barrels, which are larger in diameter in the centre than at any other part, there is a constant intermingling of the powder grains, and consequently a much more uniform action. R.L.G. remains in the barrels for 40 minutes. With this powder, and generally speaking with all larger grained powders, a little graphite is used to obtain a better surface; ½ oz. to the 100 lbs. of powder is the quantity employed. This gives a fine silvery surface to the grain, but care must be taken to use the proper description of black lead, as there are some descriptions sold which do not answer the purpose at all. It must be remembered that black lead is really an impurity, and that therefore it should be sparingly applied to powder. It is never used with any of the fine small-arm powders, but only with powders intended to be used in large charges, and with the express intention of giving them a surface which will if anything retard rather than quicken ignition. A great deal of the inferior blasting powder which is sold nowadays is polished with black lead to a high degree of brilliancy, but it is needless to remark that the lustre it possesses is no test of quality.

The friction together of the grains in the glazing barrels necessarily generates a good deal of heat. Some of the fine-grain powders which require a much longer time in glazing come out of the barrels so hot as hardly to admit of the hand being plunged in them. In all cases the heat generated is so great as to cause the powder to part with almost all its moisture, but as there is little or no escape for it, it condenses on the interior of the barrels and forms a hard coating with the powder dust. All powder "sweats," as it is called, in the barrels, to a considerable extent.

The glazing process not only polishes the grains, but tends to rub off their more prominent angles, and to bring them to a rounded form. The theoretically perfect form of powder grain is a sphere, so that the longer the glazing process is continued the more the grains will tend to approach this form. R.L.G., however, is so firm in consistency as to show little or no rounding after 40 minutes glazing. It generates, however, a little dust, and requires therefore a second dusting to get rid of this, and of any loose particles of black-lead which may not have adhered to the grains. This second dusting is done in the same reel covered with the same description of dusting cloth (24-mesh canvas) and for the same length of time, as the first dusting, described above. On leaving the reels the powder is now perfect in glaze, appearance, and freedom from dust, and requires therefore only to be stove-dried to be fit for issue. A description of the stoving is given further on.

Dusting and Glazing of Powders of the R.F.G. Class.

R.F.G., on the other hand, and all fine-grain powders of its class, require quite different treatment from the R.L.G. and such powders. The *foul grain* as it comes from the granulating machine, being very small in size and full of dust, could not be dusted in a horizontal reel

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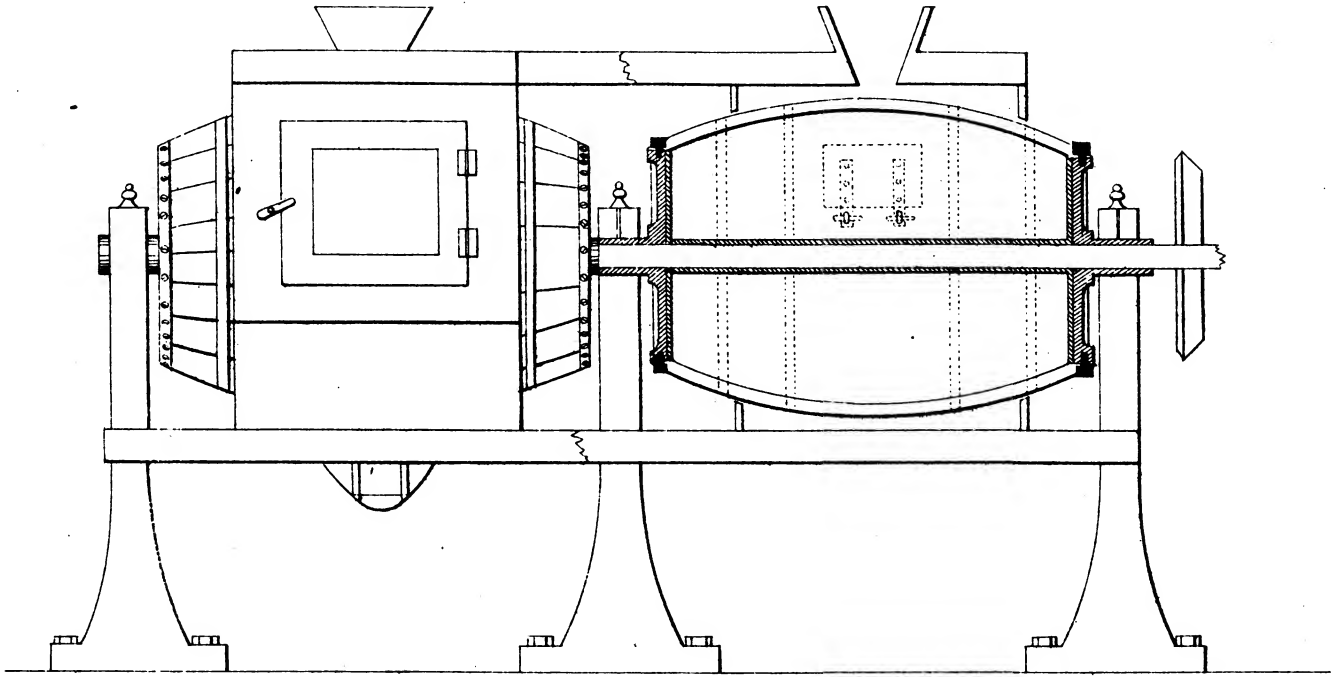
ELEVATION & SECTION OF A SET OF GLAZING BARRELS



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without choking up the meshes of the dusting cloth. It is therefore merely run through a slope-reel covered with 24-mesh canvas. This size of mesh is a very large one for such a fine powder, and though therefore reeling in this manner is a much less effectual operation than reeling in horizontal reels, it removes a good deal of the dust. The powder, still in a dusty state, is then transferred to the glazing barrels, along with some larger fragments of the powder which are put in to increase the friction, and are afterwards sifted out when the glazing is finished, and run in them for *five and a half hours* at a speed of 34 revolutions a minute. This long glazing rubs off all angles and corners of the grains which might form fresh dust, and imparts a sort of dull polish to the grains. To get rid of still more of the dust the powder is again run through a slope-reel, working at the same speed as for the first dusting, viz., 40 revolutions a minute, but covered with a somewhat finer description of canvas dusting-cloth containing 28 meshes to the inch. It is then placed in the stove for 24 hours.

There is a certain amount of dust present in the powder even when it goes into the stove, and the action of ladling it out into the stove trays and transferring it from them to the barrels when the drying is over generates a little more. To get rid of this a third dusting, termed "finishing," is necessary with all powders of this class. This third dusting, owing to the powder being now thoroughly stove-dried, and therefore firmer in grain, can be done, and only effectually done, in a horizontal reel. The reel used is covered with 28-mesh canvas, and makes about 45 revolutions a minute. The powder remains in it 2½ hours, and on quitting it is perfectly free from all traces of dust, and therefore fit to be placed in the barrels and issued for use.

Stoving.

It remains only to describe the operation of stoving powder. This is now done in large chambers, heated with steam pipes. In former days "gloom" stoves, as they were called, were universally used. These were drying rooms, having a large metal dome built into one wall, under which dome a fire was made. The surface of the dome was kept hot enough to maintain a high temperature in the room, but there was always great risk of overheating, and constant danger. They have, therefore, almost universally been superseded by steam stoves. One of the last, in use at the Roslin gunpowder works near Edinburgh, exploded last year. The present steam stoves consist of large chambers having an arrangement of steam pipes running along the floor, and provided with double doors, which can be closely shut, and with ventilators at top and bottom, which can be closed or opened from without, so as to increase or lower the internal temperature. The temperature, which is maintained at from 125° to 130° Fahrenheit, is regulated according to the readings of a large thermometer placed in the interior, but sufficiently near a small window closed with a shutter and thick pane of glass to admit of its being read from without. The stove is fitted internally with wooden racks, on which are placed the trays (either of sheet copper or of wood with a canvas bottom—both are in use at Waltham Abbey—) for containing the powder. The steam pipes run along the floor, there being one supply pipe on one side of the chamber leading directly from the boiler outside, from which a large number of transverse pipes of large diameter are laid across the interior, terminating in another smaller pipe parallel to the first, which conducts the condensed water into a tank outside. As the transverse pipes are liable to considerable expansion and contraction,

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they are connected with the latter pipe by S-shaped coils of smaller piping, which bend a little either way, and so admit of all the joints being kept tight without risk of fracture. The steam is generated in a boiler placed in a building apart from the drying chamber. Each drying chamber is limited to contain 50 cwts. of powder.

Generally speaking the stoves are charged in the morning, and are then locked up, no one being allowed to enter till the drying is completed. The stoker is not allowed to have access to the stove. All he has to do is to keep up the fires and regulate the temperature of the interior of the chamber by means of the ventilators. The pipes are so arranged that there can be no possibility of overheating. After remaining at least 18 hours at the full drying temperature the stove is allowed to cool down, so that the workmen can enter it and empty the powder from the stove trays into barrels. The powder is generally 24 hours in the stove altogether, being put in one morning and withdrawn the next, but does not actually get more than 18 hours of the full temperature, as the heat of the chamber must be lowered to admit of the workmen remaining in it when putting in or withdrawing the trays which hold the powder.

In the case of R.L.G., the powder when withdrawn from the stove is placed at once in the barrels and sent to the heading-up house to be headed-up for issue.

But in the case of R.F.G., and similar fine-grain powders, as has been remarked, a third dusting is requisite to remove all traces of dust and to fit them for service. This is termed "finishing," and is done in a horizontal reel. The particulars of the finishing process have been already given.

Glazing is stated to affect the qualities of gunpowder very considerably, but not nearly to the same extent as variations in density or in size of grain. There appears, however, to be no actual proof of the statement, and this much is certain, that with very large charges extra polishing with black lead produces no appreciable difference in explosiveness. It is probable, however, that with small charges the slowness or quickness of the charge is materially affected by the greater or less smoothness of the surface of the powder grain. A powder which has a rough, porous, and dusty surface is stated to afford a better hold to the flame as it reaches it than one with a surface highly polished. This *may*, however, be only a deduction from observations of the behaviour of other substances when exposed to ignition, and requires to be established by further experiment. A piece of wood, for instance, will be more likely to catch fire when passed quickly through flame, if it has a very rough surface with the fibre standing out from it, than a perfectly smooth piece would. In all probability something of the same sort happens with powder. Under this impression, and with the express intention of retarding somewhat the quickness of ignition, R.L.G. powder, and most experimental powders which have been tried for ordnance, have been always glazed as highly as possible. When blacklead is used, as is the case with R.L.G., there must be of course a thin layer of the material over the powder grains. This will in all probability still further lessen the quickness of ignition.

One undoubted good effect which a high degree of glazing imparts to gunpowder is, that it enables it to withstand damp, and transport much better than unglazed powder would. A polished surface is less liable to absorb moisture, and from its smoothness less likely to wear away other surfaces with which it comes in contact. Hence R.L.G. of all powders appears to preserve its qualities best, and never, except under exceptional circumstances, generates any dust.

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The quantity of powder which may be dusted or glazed at one time, or kept in a dusting or glazing house, is not fixed by the Act of Parliament. The Act, however, states that the quantity of powder which may be kept at any one time in such houses shall not exceed what is actually *necessary for their supply and work*. But as nothing is fixed as to the quantities which are necessary for the supply and work, the decision is left to the manufacturer. Fortunately accidents in dusting and glazing houses are comparatively rare; between 1859 and 1870 only four were reported; fifteen lives were lost in these accidents.

The quantity which may be stove-dried at one time is limited to 50 cwts. (56 barrels), but, as in the cases of press and granulating houses, no limits are laid down for the distances between stoves and other powder buildings. And, strange to say, no limit is fixed to the quantity of powder which may be kept at one time in the building. As in the case of dusting houses, the quantity that may be kept in stoves at one time is not to exceed what *is necessary for the immediate supply and work* of such houses. This practically leaves the quantity of powder to the discretion of the manufacturer, and it is a common practice to accumulate large quantites in stoves and dusting-houses, which are thus made to act as expense magazines, a practice which must be most dangerous.

Explosions of steam-stoves are comparatively rare, yet two have happened recently. In 1862 a steam stove at the Ballincollig works exploded, killing two men who were in the building; and in 1867 another one exploded at the Melfort works in Argyleshire, fortunately without loss of life, but causing great destruction of property from the subsequent explosions. Various causes have been assigned for such accidents.

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CHAPTER XII.

MANUFACTURE OF PELLET AND PRISMATIC POWDERS.

CONTENTS.—Manufacture of powder in the form of prisms, cylindrical pellets, spheres, &c.—Steps which led to the introduction of such powders.—A hasty conclusion as to improving the old powder arrived at.—Causes for it.—Russian and Belgian experiments.—Fundamental parts of every pellet or prismatic machine.—Safest arrangement of these.—How the pellet is pressed.—Any form can be given to pellets.—The Russian machine.—Can only be worked with grain powder.—English machine supplied by hand; reason for this.—Considerations which led to the construction of the machine in use at the Royal Gunpowder Factory.—Description of the machine: plan; section.—Action of the machine.—Time of pressing.—Sticking of the punches.—Form of pellets hitherto made in this country.—Spherical pellets.

HAVING now described the manufacture of powder as generally carried on, it remains to give some account of the special powders made in the shapes of prisms, cylindrical pellets, or spheres, and of the machines used for their manufacture. To repeat what has already been stated there are two ways of forming the incorporated materials of which gunpowder is made into grains or fragments suited for use in guns:—

1st. By compressing the powder-meal into flat cakes in a hydraulic press, and then breaking up the cakes into irregularly shaped grains or pieces, which are afterwards sorted into sizes by sifting, and then glazed or polished by friction.

2nd. By compressing it at once into regularly shaped masses in moulds with metal punches.

In the former case the finished powder consists of a collection of angular fragments of irregular shape, no two being alike; in the latter, of a number of uniform pellets (cylindrical, spherical, or prismatical, as the case may be) all exactly alike in size and shape.

Though these pages are devoted to the questions of *manufacture* and *proof* of different powders, some account must be given of the steps which led to the introduction of powders of the latter class.

On the introduction of rifled artillery it soon became apparent that the ordinary powders in use were greatly too sudden in their action for the powers of the guns. This led to several suggestions with the view of modifying the explosiveness of charges of powder. The Americans seem to have been the first who made experiments in this direction. They took powder-meal and compressed it by hydraulic pressure into flat discs the size of the bore of the gun. These discs or cakes, the invention of Dr. Doremus, were brought to this country and tried, but the results obtained with them were very irregular and unsatisfactory. The questions of variations of the density of powder and of the effect which such, especially when combined with variations in shape and size of grain, could not fail to produce, began to attract attention. Those who studied the subject must have soon become aware of the immense advantage to be derived, not only from increasing the density of powder, and thereby lessening explosiveness and consequent strain on the gun, but from uniformity of density and shape

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of the grain as affecting regularity of effect. It seems to have been somewhat hastily decided that there was no use attempting fresh experiments with powder made in the usual way, or to improve its manufacture. The great variations in density shown to exist in the service powders of that day by the use of the densimeter, appear to have been considered as inseparably consequent on the mode of manufacture. Unfortunately some experiments made at the time still further strengthened this conclusion. Some powders of very large size, made by breaking up press-cake with mallets, were prepared and tried, but were found to exercise a most destructive effect on the guns. This arose simply from the fact that no attention had been paid to the density of the samples submitted, an all-important point, or rather that the means used to test the density of the samples during manufacture, viz., the cube-box, were insufficient. It is perhaps needless to state that now it is an ascertained fact that a powder of a very high and perfectly uniform density, and of a very uniform shape of grain, *can* be made from ordinary press-cake, and that such powder gives excellent results. However, at the time of which we are speaking, the efforts of the artillerymen of all nations were directed to the manufacture of powder in a new way altogether, and the idea was generally adopted that the only way to make a powder of a high and uniform density and regular shape, was to *form each grain or constituent portion of the powder, separately*, by compressing the powder-meal in metal moulds with metal punches.

The Russians were the first to make a powder of this class; this is the powder now known as *prismatic*, because each grain, if it may be so called, is in the form of a six-sided prism, 1 inch in height, perforated with holes which run through it. The Belgians followed, with a powder made in the form of cylindrical pellets, and in 1867 the Gunpowder Committee recommended the adoption in this country of pellet-powder for all large charges. The manufacture of pellet or prismatic powder then, consists in shaping powder-meal by compression into regularly shaped pellets or prisms. It has been carried on extensively for some time in Russia, to a smaller extent in Prussia and other countries, and on a small scale in the Royal Laboratory, Woolwich. Now a large machine on a new principle has been erected at Waltham Abbey, with which to carry on the manufacture.

The three fundamental parts of every machine used for making this class of powder are: 1st, a mould in which to place the powder meal; 2nd, a punch accurately fitting the mould, with which to compress the powder; 3rdly, some appliance for pressing the finished pellets out of the moulds.

The safest arrangement for combining these three is shown in the accompanying cut: A is a small charge of powder placed in the mould, the bottom of which is closed by a tightly fitting punch or piston (B) which fits it accurately. This punch has a shoulder on it on which it rests loose on a 2nd plate C, underneath the mould plate. The lower end of this punch rests on the upper surface of the hydraulic ram D. An upper descending punch (E) of larger diameter than the mould can be brought down on the surface of the mould plate either by a screw or by hydraulic pressure, so as to close the mould. With such an arrangement, which closely resembles that of the small machine used in the Royal Laboratory, a pellet can be safely made, firstly, by bringing the top punch down on the plate and fixing it there so as to confine the powder; secondly, by raising the lower punch by means of the ram till a proper amount of compression has been given to the powder; thirdly, by stopping the pressure from beneath and raising the upper punch; and fourthly, by raising the finished pellet out of the

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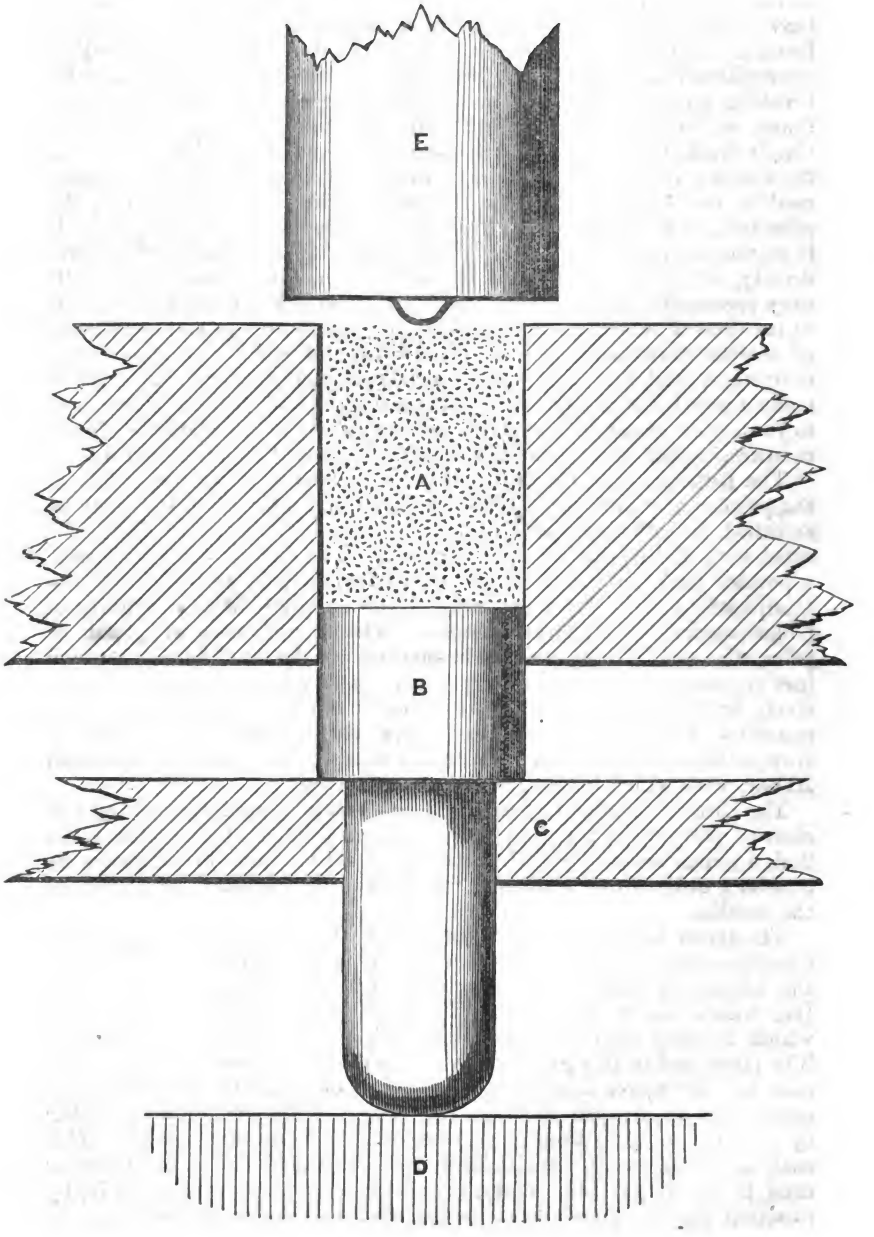
mould by the pressure of the ram underneath. It is plain that any form can be given to the pellets by altering the shape of the moulds and punches, and that hollows or perforations can be made in the pellet if required. There is no difference really between pellet and prismatic



powder, except in the shape. A machine exactly similar to the one above described could be used for making powder into hexagonal prisms perforated with holes, just as easily as for forming cylindrical pellets.

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The Russians, however, employ a machine of a totally different description, of which an account, with two lithographs, will be found in the "*Tour of Artillery Officers in Russia*," 1867. In this machine the mould plate contains only six hexagonal moulds, and has a lateral movement backwards and forwards underneath a hopper filled with the powder to be compressed. The mould plate fits closely underneath the hopper, and on sliding in receives a charge of powder in each of the moulds; it then slides out again into a position directly between the upper and lower punches. This outward and inward travel of the mould plate is effected by a cam, so arranged that the plate is at perfect rest while the punches are acting. The punches are not worked by hydraulic power, but by a cam and eccentric on a shaft driven by machinery. Their upward and downward motion is therefore continuous, and once the hopper is filled with powder the action of the machine goes on without stopping till the whole of the powder in the hopper is converted into prisms. This appears to be a decided advantage, since by employing several machines at once all driven from the same shafting, the manufacture of prisms can be carried on with tolerable rapidity. It is found, however, that self-feeding machines of this description when used with *powder-meal*, that is, with the incorporated material after being broken-down, are very apt to clog and choke. Powder meal when it contains a proper amount of moisture, no matter how finely it is broken up, very speedily cakes together again into lumps. The Russians and Prussians have accordingly found that the most satisfactory results are obtained with their machines when grain-powder is used instead of powder-meal. In other words, they first make powder in the usual way, and then employ the finished powder for conversion into prisms. This must of course add greatly to the expense of the process. But in the English machines, and all others in which the filling of the moulds is done by hand, the powder meal can be taken after its first stage of manufacture, and all the expense and trouble of pressing it and granulating it in the ordinary way avoided.

This will explain the reason for one feature of the new machine which has just been erected at Waltham Abbey, viz., the very large number of moulds which are filled and pressed at each operation. It was thought better to adhere to the process of filling the moulds by hand, and to obviate the loss of time so occasioned by making arrangements to fill and press a large number at once, than to attempt the self-feeding arrangement of the Russian machines.

Some other considerations which led to the details of the new machine must also be given before the machine is described.

As soon as it was determined to commence the manufacture of pellet powder on a large scale, the principal point which had to be determined was how to obtain pellets of uniform density.

With regard to this it was at first assumed as an ascertained fact that the best way, indeed the only certain way, to manufacture pellets of uniform density, was to subject each pellet to exactly the same pressure. A machine was therefore designed on the plan of the cap-machine in the Royal Laboratory, in which each of the lower punches rested on the short arm of a weighted lever, so that in pressing each pellet would receive the full amount of pressure necessary to raise the weight. It was found, however, that a machine on this plan, if made of any great size, would be exceedingly cramped and complicated, and the idea was wisely abandoned. We say wisely abandoned, for even if the arrangement had been carried out, the pellets made by such a machine would in all probability have showed greater variations of density than those made by pressing powder meal to a certain *distance*. If the reader will turn to

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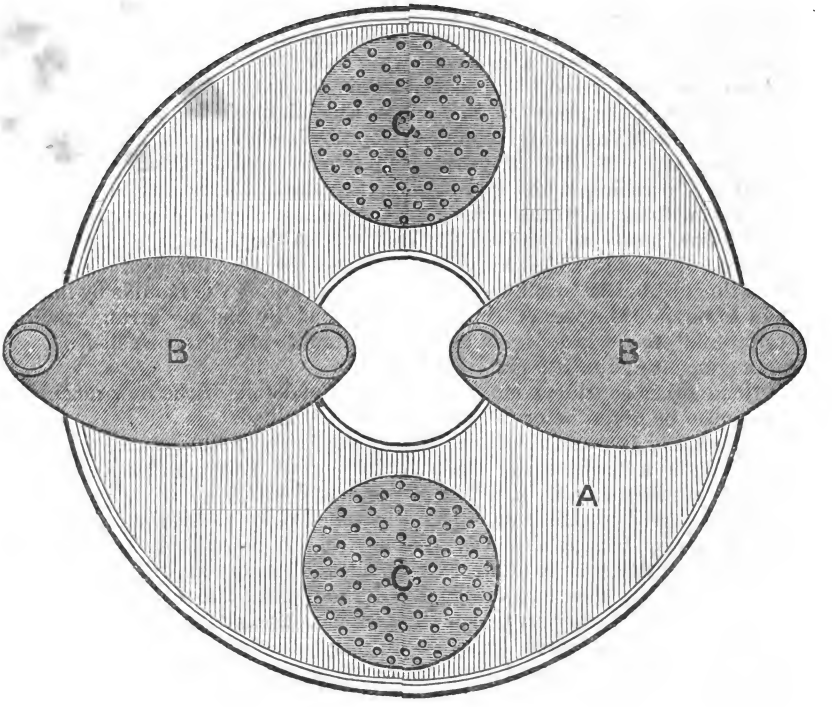
the remarks made on the subject of pressing powder in the hydraulic press, he will find it stated that experiments have fully proved that it does not follow that uniform density is obtained by subjecting powder-meal to a uniform pressure; that on the other hand, powder-meal possesses very varying powers of resistance according to the conditions in which it is as regards moisture, and according to the conditions under which it is pressed, and that the only safe way of ensuring tolerable uniformity of density is to compress a certain amount of meal into *a certain space.* It follows, therefore, that a machine designed to give each pellet exactly the same amount of pressure in tons or lbs. would not necessarily turn out pellets of uniform density.

As the arrangement of punches previously described appear to fulfil all the requisites for the safe working of a pellet machine, it was adopted for the machine at Waltham Abbey. But to obviate the loss of time caused by hand-filling, the mould plates were made with a large number of moulds, so that a large number of pellets (400) could be pressed at one operation.

The general arrangement of the machine must now be described. It is shown in plan on a small scale in the cut. A is a circular revolving table carrying four mould plates. Each mould plate contains 200 moulds. B B are the top cross-heads of the rams. There being four mould plates two are being pressed at the time the other two are being filled. Thus 400 pellets are pressed at one time. The revolving table



consists of a framework of gun metal, having the top boarded over to prevent the powder falling down into the machine. It is traversed round by hand by means of a rack and pinion. The mould plates are of gun metal, being made double, as shown in principle in the cut on page 76.

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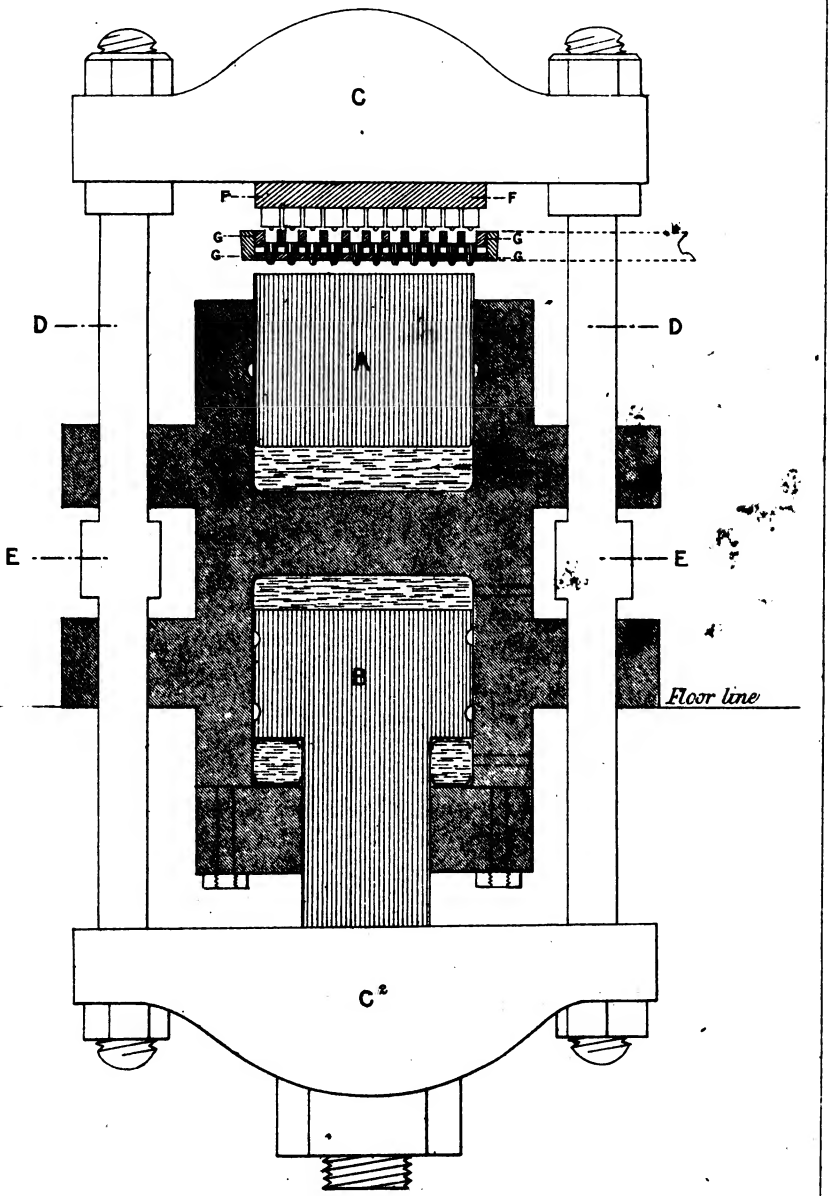
Plate 23.

PELLET MACHINE.



SECTION AND ELEVATION
Scale $\frac{1}{32}$

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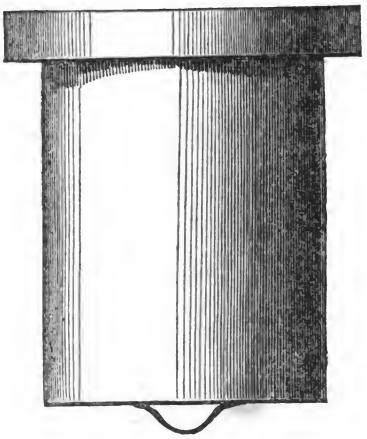
The punches are of steel, of the shape shown in the cut referred to. The upper punches are of this shape—



and are also of steel. They fit into holes in a gun-metal plate secured to the cross-head of the rams.

A section of one of the rams will now explain the action of the whole machine. It is given in the accompanying illustration (see Plate 23). The ram is double, there being an upper one A to press the pellets, and a lower one B to raise and lower the cross-head C. The upper cross-head is connected with a lower one C 2 by powerful side-rods D D of wrought iron. On these rods there are stops E E, so adjusted as to admit of the upper cross-head being brought down only far enough to admit the upper punches to touch closely the mould plate, and close the openings of the moulds. F is the upper plate fixed to the cross-head, and carrying the upper punches. G G is the lower double plate, which is fixed in the revolving table, and which carries the lower punches hanging loose in it.

The action of the machine will be understood by referring to the description of the upper and lower punches, *ante*. The rams are worked by means of a hydraulic accumulator, loaded so as to give a pressure of 1,000 lbs. on each punch in the mould plate. With this pressure any degree of density can be given to the pellets by keeping up the pressure a longer or shorter time, as required. From 10 to 20 seconds generally suffices to give the density required. The punches being of bright steel were found at first to oxidize very rapidly from the moisture squeezed out of the powder, and consequently to stick in the mould plate and impede the action of the machine. This has been overcome to some extent by browning or blueing the punches.

The particular form of pellet which has hitherto found favour in this country is a small cylinder having a slight hollow or indentation in the upper surface. The cylindrical form has, however, been adopted, not from any idea that such a shape was likely to gain the best results, but because such a shape was most easy to manufacture. From the remarks made on the shape and size of grains previously, the reader will understand that the spherical form is the one of all others which is most to be desired, and the more nearly this form is approached the better. This is from considerations of the *rate of burning* alone; but manifestly a spherical form offers many other advantages in the way of being able to withstand handling and transport better than any shape which pre-

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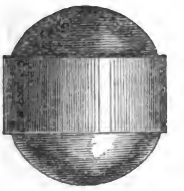
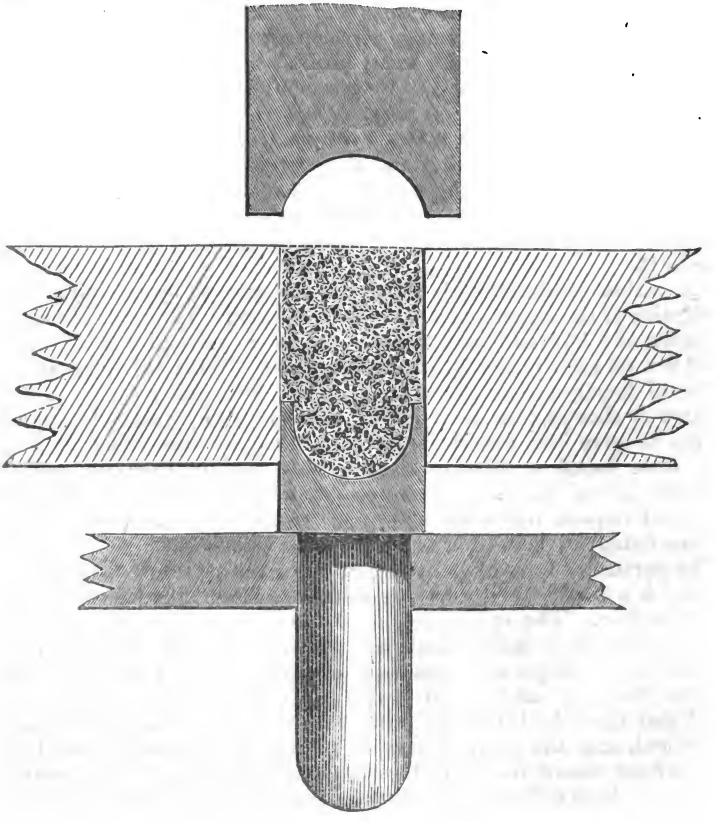
sents sharp angles. But it is not possible to form perfect spheres with a pellet machine if the question of density is to be taken into account, for once a sphere is formed by the action of two hemispherical hollow punches no further pressure can be imparted. However, a very near approach can be made to it, and pellets have recently been made at Waltham Abbey of this shape—



These are made in the machine just described by means of punches having hemispherical hollows made in their faces, as shown in part section in the cut below. Such pellets, proposed by Colonel Younghusband, R.A., F.R.S., the Superintendent, approach sufficiently near to the spherical shape, and the band left round them by the action of the punches can be rounded off by subjecting them to the action of the glazing barrels. It is confidently anticipated that such pellets, when glazed, will give excellent results, not only as regards firing, but as regards capability of withstanding damage from transport, &c.



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CHAPTER XIII.

EXAMINATION AND PROOF.*

CONTENTS.—Points to be determined in examining and proving gunpowder.—Each stoving proved separately.—Colour.—Glaze.—Hardness and crispness of grain.—Freedom from foreign matters.—Test for perfect incorporation: flashing, remarks on.—Size, shape, and proportion of grains: sifting proof.—Density of powder: how it is tested.—Slight variations in density cannot be detected by the cube-box.—Description of the densimeter.—Use of densimeter: example.—Firing proof, how conducted at Waltham Abbey.—The old mortar proof.—Proof guns and rifles used at Waltham Abbey.—Plan of proof range.—Le Boulengé's chronoscope.—Analysis of gunpowder.—Proportions of ingredients which may be expected in Government powder.—Excess of sulphur.—Hygroscopic test.—Proof registers kept at Waltham Abbey.

THE examination and proof of new gunpowder as now carried on at Waltham Abbey has for its object to ascertain—

1. If the powder have a proper colour to the eye, a proper amount of glaze, a sufficiently hard and crisp texture, and if it be free from dust and perfectly clean.
2. If it be properly incorporated.
3. If the grains be of the proper size and shape, and if the different size of grains present be in the proper proportion.
4. If the powder be of the proper density.
5. If the action of the powder when fired be uniform, and up to a fixed standard.
6. If it contain the proper proportions of the three ingredients; and,
7. If it possess a sufficient power to withstand the absorption of moisture.

The two latter points are generally decided in the Chemical department at Woolwich.

Each stoving of powder is proved separately. The stoving, that is, the total amount taken out of the stoves each morning, is taken as the unit, as it is practically the result of one day's work. The powder, therefore, of which it is composed has not only been made under exactly the same conditions, but has been to a great extent intermixed throughout in the granulating, dusting, and glazing processes, and is, therefore, practically uniform.

Taking the various divisions of the proof *seriatim.*

I. *Colour, Glaze, Hardness and Crispness, and freedom from Dust and foreign matters.*

In the case of powder made at Waltham Abbey, the above points would of course be well attended to in the course of manu-

* The substance of this chapter has already appeared in the *Proceedings of the Royal Artillery Institution.*

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facture, and any variations in them would be checked at the time, so that the finished powder would not be subjected to examination or proof till up to the standard in such particulars. But in the case of other powders, some description must be given of the way such points are judged. The qualities enumerated can be judged by the eye and hand alone, and require of course a certain amount of experience to enable an observer to arrive at a trustworthy opinion.

a. Colour.—The colour of finished powder depends on two points principally; first, the colour of the charcoal of which the powder has been made, and second, the amount of moisture that has been added to the charges before leaving the incorporating mills. The more underburnt the charcoal is the browner will be the powder. Some powder made from very slack-burnt charcoal has a reddish tint, which is very easily detected on crushing the grains to dust. It is needless to say that in the point of colour, the powder under examination must be the same as the standard powder of the particular class to which it belongs. Any great variation in the charcoal used would no doubt be detected in the subsequent processes of proof, for a powder made with underburnt charcoal will give a decidedly higher velocity than one made with a more highly burnt and consequently denser charcoal, and it will be found to absorb moisture more readily than the latter. Underburnt charcoal appears to offer certain advantages in small-arm powders, so that the reader should remark that in such matters there is no *absolute* rule to lay down. All examinations of the colour of powder must be comparative.

As regards the other point, the amount of moisture which has been added to the charges in the mills, it is found that when the charges are taken off the mill-beds with an excess of moisture in them, and are subjected to pressure soon afterwards, the resulting powder is harder and of a blacker colour than if made otherwise. If two powders therefore be found to be of equal density, and if the one be *blacker in colour and harder* than the other, it has been worked *heavier*, that is, taken off the mill bed with a greater amount of moisture in it. There is no test for hardness, which can only be estimated by breaking the grain between the finger and thumb.

A powder which has been worked with a very great amount of moisture may be expected to give indifferent results when flashed, but practically the differences which powders present in this respect are seldom of any consequence.

b. Glaze.—The subject of glaze has been already fully treated on, under the head of dusting and glazing. It is unnecessary therefore to say more on the subject here. Examination as to this must also be comparative, as must also be that for—

c. Hardness and Crispness of Grain.—In these matters experience is the only safe guide.

d. The quality of Freedom from Dust or foreign matter can be more easily tested.—All powders should be absolutely free from dust. The only way to make sure of this is to pour rapidly a quantity of the powder from a bowl held two or three feet above the barrel in a good strong light. If there be any loose dust it will be readily detected. Powder that is glazed with blacklead should also be perfectly free from loose particles of the blacklead, and should in no case soil the fingers. The presence of other foreign substances in powder need not be alluded to here, as none such could occur in new powder. The reader will find under the head of *examination of returned powder* some remarks on this subject.

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II.—*Incorporation.*

This is tested by "flashing," that is, by burning a small quantity of the powder on a glass, porcelain, or copper plate. 8 drs. of the powder is generally flashed. This quantity is put in a small copper cylinder resembling a large thimble in shape, and the cylinder is then inverted on the flashing plate. This provides for the particles of the powder being arranged in pretty nearly the same way each time, which is an all-important point in flashing. The decomposition of the powder will be more thorough if the powder be thrown together in a small conical heap than if it be spread out in a thin layer on the plate, hence, for comparison of different powders, they should be placed on the plates as nearly as possible under the same conditions.

If the powder has been thoroughly and effectually incorporated the small charge placed on the plate will "flash," or puff off, when touched with a hot iron, leaving only some smoke-marks on the plate. A badly incorporated powder will, on the other hand, leave specks of undecomposed saltpetre and sulphur, and will therefore leave a dirty residue. But the "flashing" test, though apparently most simple, is one which, like the examination by eye and hand, requires experience to enable the observer to form an accurate judgment. Though a very badly incorporated powder could at once be detected, it is by no means so easy to judge between two powders, both tolerably good, as to which has undergone the most thorough incorporation. Flashing should therefore be constantly practised with all classes of powders, and it is useful to keep some samples of bad powders to flash occasionally for comparison. Powder which has once been subjected to and injured by damp will be found to flash very badly, no matter how carefully its incorporation may have been performed. This arises from a partial solution of the saltpetre having taken place, causing a consequent disturbance of incorporation.

III. *Size, Shape, and Proportion of the Grains.*

The *shape* of the grains can, of course, be judged by the eye alone. The principal point to observe is whether there be any elongated flat scales amongst them. If this be the case, the powder will be rapid in its action (*see* Chapter X. on Size and Shape of grain), and therefore injurious to all calibres of our modern artillery. The grain should be as compact in shape as possible, approaching as near to the cube or sphere as granulated powder can be expected to come.

The size and proportion of grain can be readily detected with the sieve. The limits of size of each powder being known, all that is requisite to decide if it be of the proper size is to sift it on the two sieves which define its size; it must all pass the one and all be retained on the other. For example, if the powder be R.L.G., the size of which is between a 4 and an 8 mesh, the powder, when sifted on a 4-mesh sieve, must all pass through it, and when placed on an 8-mesh* sieve, must all be retained on it. We say *all* retained on it, but practically a small quantity will always pass the lower size of sieve. This arises from the fact that in the granulating machines the powders are separated on *sloping* sieves, which do not allow the smaller par-

* It is, perhaps, hardly necessary to say that by a 4, an 8, a 16 mesh, &c. sieve is intended a sieve with *four divisions to the inch linear, not four openings in the square inch.* Thus, a 4-mesh sieve has 16 holes in the square inch; an 8, 64; a 16, 256; and so on.

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ticles to pass through so easily as horizontal ones would. The quantity, however, which passes should be very small; in the R.L.G. it must not exceed one sixteenth of the whole.

The sifting we have described, though it shows that the powder is within the limits fixed for its size, does not, however, convey any information as to the *proportions of different sized grains* contained in the powder. To explain what is meant: a sample of R.L.G. must pass a 4-mesh and be retained on an 8; but the sample may either consist entirely of grains *just small enough to pass the* 4, or again, of grains *just large enough to be retained on the* 8. In the first case the sample would consist entirely of *large* grains, in the second entirely of *small*, the effect of which would be very different. Powder made in the granulating machine generally presents a tolerably regular gradation of different sizes of grain, and it is the object of the proof-officer to discover if this gradation of grain be properly preserved in the sample under his examination, for too great a proportion of small grain may have been either accidentally or purposely introduced. The sample must therefore be sifted into the different sizes of grains of which it is composed. Thus R.L.G. is sifted on a 4-mesh, a 6-mesh, and an 8-mesh; and the proportion should be as follows:—

¾	should be retained on the	6
¼	„ „	8

But, as said above, a small quantity will generally be found to pass the 8; this must not exceed one-sixteenth.

If one pound be sifted it should therefore be distributed as follows:—

4-mesh to 6-mesh	12 oz.
6-mesh to 8-mesh	3 oz.
pass 8-mesh	1 oz.
	16 oz.

This class of powder is the only one for which a specification of manufacture has been drawn up, so that it will be sufficient to quote it as an example of the sifting referred to.

IV. *Density.*

This, as has already been stated, is the most important quality of gunpowder, and must be most accurately determined, which can only be done by means of the mercury densimeter. The old gravimetric test, that is, "cubing," or weighing a cubic foot of the powder, gives a fair indication of considerable variations in density, but may mislead from differences in shape and size of grain. It is, moreover, perfectly useless to attempt to detect slight variations of density—variations which though slight in degree yet exercise immense effect on the qualities of the powder—by means of it. The cube-box is therefore no longer used at Waltham Abbey, being entirely replaced by the densimeter, with which the density of the pressings and glazings are ascertained before the manufacture of the powder is carried on further.*

The densimeter (see Plate 24) consists of a barometer tube (*l m*), supported on a stout metal stand (*a*), and having a cock (*d*) at the bottom by which it can be closed or opened. Attached to the top of the tube is a flexible tube communicating with an air-pump, by means of which the

* The pressings are numbered and granulated separately, and a specimen of the grain from the machine sent down for examination as to density.

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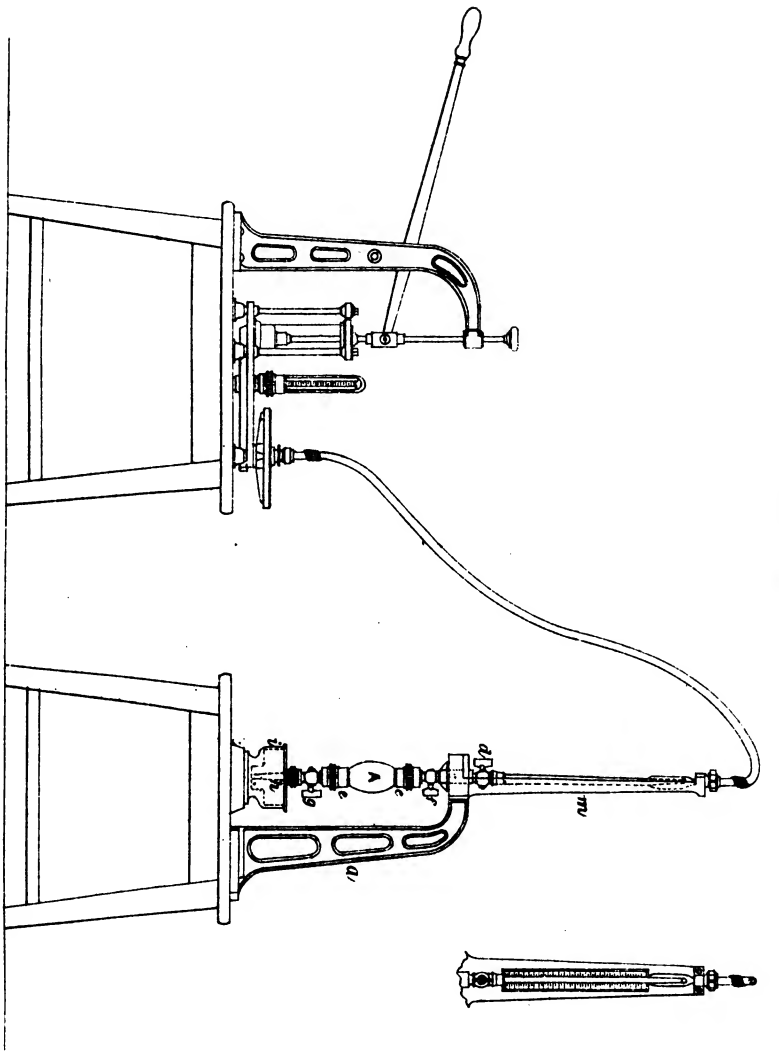
Plate 24.

DENSIMETER.



Scale $\frac{1}{13}$

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air can be exhausted from the tube. A glass globe (A) fitted with metal collars ($e\ e^1$), on which again are screwed other collars provided with stop-cocks ($f\ g$), can be attached to the bottom of the barometer tube by means of a closely fitting screw. The lower collar of this globe is provided with a nozzle (h) which dips into an iron bowl filled with mercury (i). If, then, the lower cock (g) be kept closed and the other ones opened, the air can be exhausted from the barometer tube and globe; and the lower cock being then opened, the mercury rushes in, rises up till it fills the globe, and continues to rise in the tube till it has attained the same height from the surface of the mercury left in the bowl as the column in an ordinary barometer stands at the time.

The process of taking the density of a sample of powder is as follows:—

The air is first exhausted from the tube and globe, and the mercury allowed to fill them. The upper and lower cocks of the globe are then closed, the nozzle is taken off, and the globe unscrewed from the barometer tube and weighed. This weight—the weight of the globe filled with mercury—is registered.

The globe is then emptied, and a definite weight of the powder (generally 100 grammes) is introduced into the globe. The globe is then attached to the barometer tube as before, the air exhausted, and the mercury allowed to enter and rise in the tube as before. The stop-cocks attached to the globe are provided with diaphragms, the upper one of chamois leather, the lower one of fine wire gauze, to prevent any particle of powder being carried out of the globe. As soon as the mercury has risen to the proper height, the stop-cocks attached to the globe are again closed, the nozzle unscrewed, and the globe taken off and weighed. This second weight—the weight of the globe full of mercury, *plus* the weight of the powder, and *less* the weight of the volume of mercury displaced by it—is also registered.

The density of the powder is then calculated by the following formula:—

$$\text{Density} = \frac{D \times 100}{(P^1 - P) + 100}$$

where D = specific gravity of mercury at the time of experiment.
P = weight of globe full of powder and mercury.
P^1 = weight of globe full of mercury alone.
100 = weight of powder employed.

The specific gravity of mercury is at	50° F.	- -	13·57
,, ,,	60°	- -	13·56
,, ,,	70°	- -	13·54
,, ,,	80°	- -	13·53
,, ,,	90°	- -	13·52

An actual example worked out is subjoined:—

	grammes.
Weight of globe filled with mercury	4138 = P^1
,, ,, powder and mercury	3434 = P
Difference -	704
Temperature at time of experiment - -	60°
Consequent specific gravity of mercury -	13·56 = D

Then D × 100 = 1356·000
$(P^1 - P) + 100$ = 804

804)1356(1·689 = density required.

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V. *Action of the Gunpowder when fired.*

This is decided by the firing proof.

It has been already stated that it is impossible to predict, from observations made with one gun, what the action of different charges of powder used with different calibres of guns will be. But this does not in any way affect the accuracy of the firing proof now employed, the only object of which is to ascertain whether certain samples of powder when fired in equal charges and under the same conditions from the proof gun, produce the same effects as have been previously obtained with standard powder of the same class. The present firing-proof is not intended and could not be employed to decide what nature and changes of powder are suitable for all arms, but is merely a means of *comparing samples of powder with the standard fixed by previous experiments*. It is not the province of the manufacturer to decide what description of gunpowder shall be employed, but to make powders in all respects identical with those decided on by the experimental committees as the most fit for use. The powders made must be not only identical in physical qualities, but must produce the same results when fired in equal charges and under the same conditions.

The firing-proof now employed affords a very perfect means of comparing the action of different powders. The old proof consisted in firing a 68-lb. shot with a charge of 2 oz. (3 oz. in the case of R.L.G. powder) from an 8-in. mortar, and comparing the ranges obtained. So much abuse has been recently heaped on the old proof mortar that it is perhaps unnecessary to say anything on the subject. But it must be remembered that its advocates did not intend it to be used for the purpose of comparing the effects of *different descriptions of powder*, any more than the supporters of the new proof make use of the perfect appliances at their command for the same purpose; but only for comparing *various samples of the same description of powder* with a standard. A proof mortar, if properly used, would probably afford a rude but tolerably exact means of comparing the strength of different samples of the same kinds of powder. We say probably, because there are so many disturbing elements in the mortar proof which were never properly eliminated, that it never received a fair trial. Now, of course, such a trial would be useless, as far more accurate and delicate means of proof are at our command. The firing proof now in use at Waltham Abbey consists in measuring the velocity imparted to a projectile fired from a gun by a fixed charge of the powder under examination. The two different classes of powder—that is, powder for cannon and powder for small arms—are tested as nearly as possible under the conditions under which they would be used, powders of the first class being tested in a 12-pr. gun, those of the latter in a Snider-Enfield or Henry rifle. The arrangements of the proof range are shown in the accompanying figure (Plate 25).

The muzzle of the gun is 180 feet from the face of the butt. The latter is filled with loose sand, and has an opening at the side to admit of the 12-lb. projectiles being afterwards dug out. The first wire screen or target is 45 feet from the gun, there being a screen of wood between them with a hole for the passage of the shot, to prevent injury to the wire screen from fragments of the cartridge, &c. &c. The second wire screen or target is 120 feet from the first, that is, 165 feet from the muzzle of the gun, and is therefore 15 feet distant from the face of the butt. The gun used for proving powder of the R.L.G. class is a 12-pr. M.L. wrought-iron gun, with Whitworth steel tube, rifled in three groves; rifling and vent special; rifling, 1 turn in 25 calibres. It is used either

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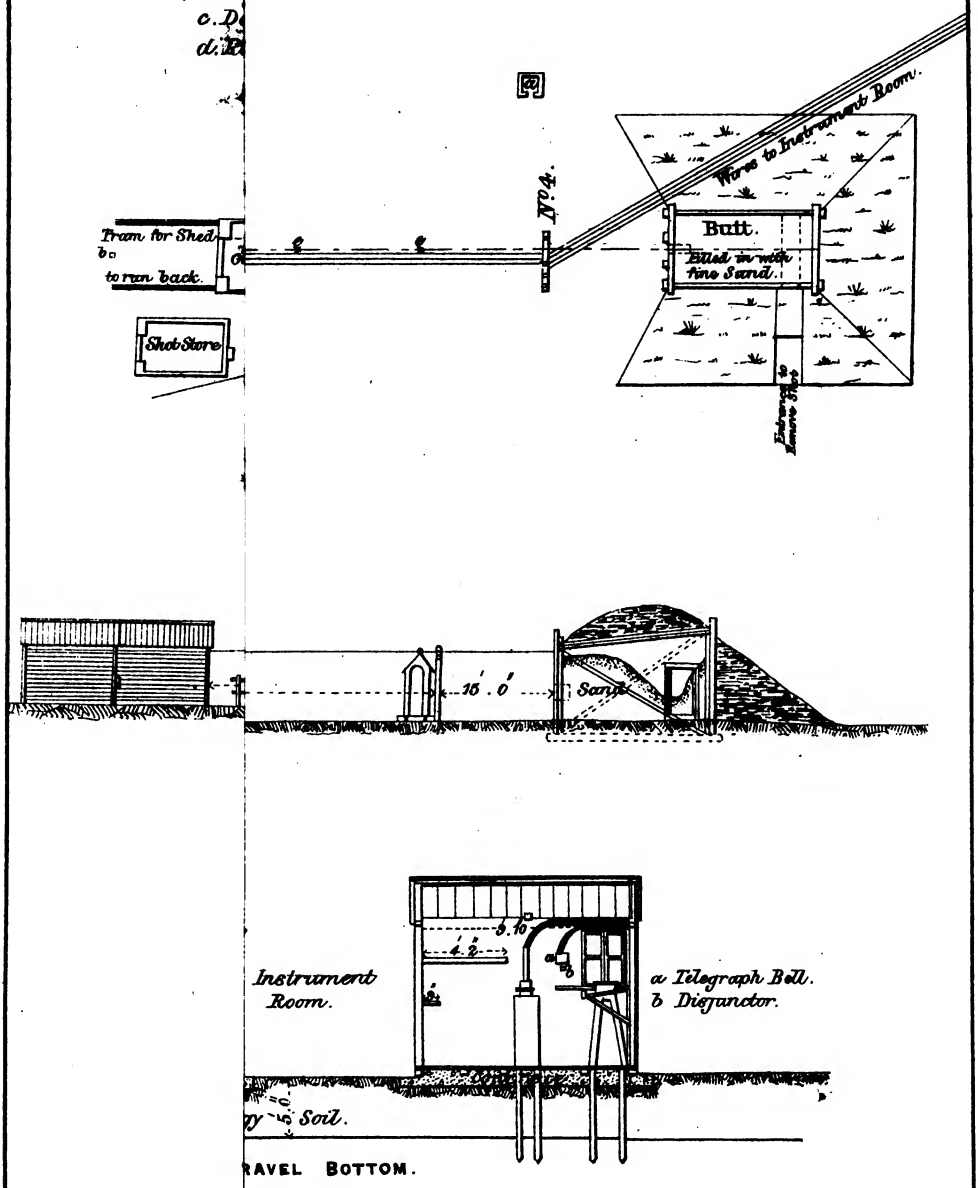
Plate 25.



Vincent Brooks, Day & Son, Lith.

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with 12-pr. shot and a charge of 1 lb., or with a 9-pr. shot and a 1¾ lb. charge. The small arms employed are a Snider-Enfield and a Henry rifle, both fired with the service ammunition.

The chronoscope used is one of Le Boulengé's, and has recently been so fully described by Lieut. C. Jones, R.A., in a separate pamphlet, that it is unnecessary to say more on the instrument here. The results obtained with it are excellent. Three shots are fired from each sample of cannon powder subjected to proof, and generally five from each sample of small-arm powder. The observations of velocity agree very closely.

It may be predicted with tolerable safety that provided the powders fired have been made of the same materials (particularly of the same description of charcoal), under the same conditions, and are of equal density and of equal size of grain, that they will give very nearly the same velocities. Any variation in density, however, will tell at once. The reader is referred to some more remarks on this subject in the chapter on the effects produced by variations in density.

VI. *Analysis.*

This is conducted under the superintendence of the Chemist, War Department, in the Royal Arsenal. Generally a mixed sample from a number of stovings is submitted for analysis, as it is unnecessary to analyse the work of every day. As these pages are intended to apply only to the actual work which is carried on at Waltham Abbey, and which has come under the writer's observation, it would be out of place to enter into the details of the analysis of gunpowder, which will be found fully detailed in various works on chemistry.

The quantity of moisture in the sample submitted is first ascertained, and then 100 parts of the dry powder are analysed. The analysis is a comparatively simple process, and may be readily performed by anyone, first, by dissolving out the saltpetre with warm water, special precautions against loss of charcoal in filtering being taken; and secondly, by dissolving out the sulphur with bisulphide of carbon. The three ingredients can thus be separated and weighed.

From the description of the mixing process at the commencement of this volume, it will be seen that 38 lbs. of saltpetre are put to the charge; in other words, that the proportions of our gunpowder are, for every 100 parts dry powder—

Saltpetre	75·248	nearly.
Charcoal	14·850	
Sulphur	9·900	

In almost every case, however, the sulphur will be found a little in excess in analysis. This is probably caused by the fact that the charcoal contains when weighed a considerable quantity of moisture, for which no allowance is made in weighing, causing an actual deficiency of that ingredient in the powder. Most recent analyses show a proportion of sulphur exceeding 10, and a proportion of charcoal under 14 per cent.

The question of the best proportion of ingredients is one which will probably be soon taken up by the Gunpowder Committee. No change in the present weights has therefore been made at Waltham Abbey, as yet.

VII. *Hygroscopic Test.*

This, like the analysis, has hitherto been conducted in the Chemical Department at Woolwich. It consists merely in subjecting dried specimens of powder to a damp atmosphere in a closed box kept

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at a uniform temperature, and weighing them at regular intervals, to ascertain the rapidity with which they absorb moisture. The following description of the apparatus used, and mode of conducting the test, is from a paper by Prof. Abel, F.R.S. :—

The apparatus, &c. required in connexion with the application of the hygroscopic test consists of the following items :—

1. *The Testbox* (*see* Plate 26). This consists of a double box ; an inner one of stout copper or sheet zinc lined with marine glue, or some other coating of similarly impenetrable character, and an outer one of stout wood (not less than one inch thick). The inner box is 12 inches square and nine and a half inches deep. There should be a space of not less than two inches on all sides between the inner and outer boxes, and this space should be filled with some non-conducting material (such as hair, wool, or felt) *very* closely packed. The boxes are closed by a double lid, with non-conducting material intervening. A small perforation is made in each lid, one over the other, of just sufficient size to permit of a tube thermometer (with long bulb) being introduced.

The inner box is provided with a movable tray of perforated copper, to receive the samples of powder to be tested ; on a level with the tray about half-way up the box, a shallow trough is fixed on all four sides of the box. The metal composing this tray is also coated with the same protective material as is applied to the surfaces of the box.

2. *A Solution of Saltpetre.*—This is prepared by saturating distilled water with saltpetre at 100° F. The solution is allowed to cool down to about 80° and a sufficient quantity is then introduced into the box to cover the bottom of the latter and nearly to fill the shallow trough. Eight fluid ounces of the solution are placed in the bottom and a similar quantity in the trough.

3. *Four shallow circular Trays,* about three inches in diameter. These trays consist of a rigid ring of copper half an inch deep, to one edge of which is soldered a disk of very *fine* brass gauze, the object being to allow the moist air in the box to have free access on all sides to the layer of powder exposed in these trays.

4. *Four Glass-stoppered Weighing Tubes,* about one inch diameter throughout and three inches in length, and having flat bottoms.

5. A small glass funnel, with a short wide neck.

6. A sufficiently delicate balance and a set of grain weights.

The mode of conducting the test is as follows :

The box should be placed in an apartment which is not liable to extreme fluctuations of temperature, so that the interior of the box may have a tolerably constant temperature, ranging from 55° to 60° F. There will be no difficulty in obtaining this result if the space between the two boxes be properly packed.

Four samples of powder are placed in the box at one time, each sample is tested in duplicate, so that two kinds of powder can be tested at one time in each box.

Two hundred grains of the powder under examination are weighed out and placed in each tray, which is gently tapped, so as to spread the grains uniformily over the surface of the gauze. When the four samples of powder have been thus arranged, they are placed in the box, which is then closed.

The thermometer is inserted, and the temperature noted after a short time ; readings are taken again some hours after the box has been closed ; and at the conclusion of the test, before opening the box.

After the lapse of 24 hours the box is opened and the samples are transferred as rapidly as possible by means of the funnel to the glass tubes, the weights of which when empty have been previously ascer-

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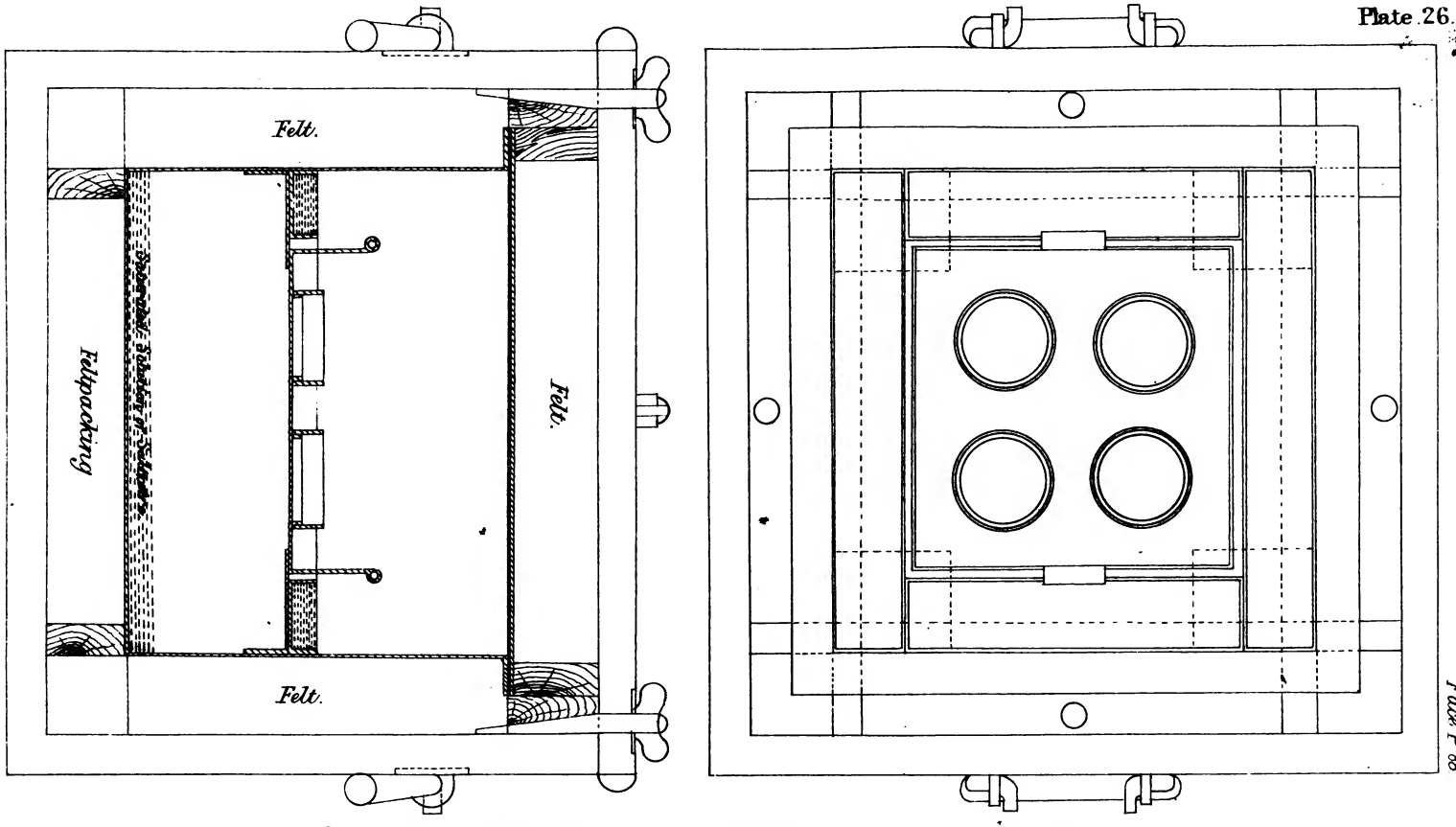

APPARATUS FOR ASCERTAINING THE HYGROSCOPIC PROPERTIES OF GUNPOWDER.

Scale of 1 2 3 4 Inches

Face P 88

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tained; they are stoppered as soon as the powder has been introduced, and the increase in weight which they have sustained is then ascertained.

Powders are found to vary very much in the rapidity with which they take up moisture; generally speaking a hard texture is unfavourable to absorption; a highly burnt charcoal is also less absorbent of moisture than a less dense one. Consequently, powders made with underburnt charcoal are found to absorb moisture more readily than others made with more perfectly burnt charcoal. As a rule, contract powder, of which the charcoal is generally underburnt, absorbs about twice as much as Waltham Abbey powder. The density of the powder affects the result to a considerable extent, at least with black charcoal powder, the absorbing power of which is diminished as its density is increased. But the comparatively high absorbing power imparted to the powder by red charcoal is little if at all reduced by an increase of density.

The quality of non-absorption of moisture is of course a most important one for powder to possess.

Having now gone over all the proofs to which gunpowder is subjected, it may be as well to show the form in which the results are recorded at Waltham Abbey.

The following is a copy of the heading of the proof book, R.L.G. powder, with an entry. This shows exactly the nature of the record kept for every stoving. As all new powder has the date of stoving painted on the barrel heads, it follows that the fullest information can always be obtained respecting any powder about which any correspondence or complaint may arise. The stovings are made up

EXAMINATION and PROOF of R.L.G. POWDER, manufactured at Waltham Abbey.

Date of Stoving.	No. of Barrels in Stoving.	Remarks on Flashing.	Sifting of 16 lbs.			Density.	Analysis.			
			4 to 6	6 to 8	pass 8		In 100 parts dry Powder.			Moisture per cent.
			lbs. oz.	lbs. oz.	lbs. oz.		Saltpetre.	Sulphur.	Charcoal.	
—	35	Very clean.	12 2	3 10	0 4	1·680	75·51	10·01	14·48	0·90

(*continued.*)

Date of Firing Proof.	Barometer.	Thermometer.		Velocity in feet of 12-lb. shot at 105′. Charge, 1 lb.				Muzzle Velocity.	Remarks.
		Dry Bulb.	Wet Bulb.	1.	2.	3.	Mean.		
—	30′·12	60°	50°	1002	1000	1007	1003	1007·8	—

into lots of 100 barrels, each lot containing generally two or more stovings. The lots are numbered consecutively, all the barrels in the lot being marked with the lot number. But to enable every particular barrel of powder to be identified, each barrel, in addition to having the date of stoving on it, has the *number of barrels in the stoving* and the *number of the particular barrel* painted on it. More detailed information on this point will be given in next chapter.

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CHAPTER XIV.

BARRELLING AND MARKING. POWDERS NOW IN USE: THEIR CLASSIFICATION.

CONTENTS.—Powder barrels, their advantages and disadvantages.—How new powder is marked when sent to Purfleet.—Specimens of markings.—Proof of powder under the old and recent contracts.—Powders now in use in the service.—Service and serviceable powders.—The new classification of powder.—Explanation of different classes.—Markings of Class I. powder.—Ditto of Classes II. and III.

THE recent W.O. circular of date 1st July 1870 (which is reprinted in the Appendix), by which all the previous circulars on gunpowder are superseded, gives so much information on all points connected with the marking and storage of gunpowder that our remarks on these subjects will be brief. To render this work, however, as complete a manual on all gunpowder questions as possible, a little must be said on barrelling, marking, and storage generally.

Finished powder is placed in whole barrels each containing 100 lbs. It has recently been decided that in the case of the "pebble" powder provisionally introduced for large charges, each barrel will contain 125 lbs. This powder being very dense occupies a much smaller space than ordinary powders, which in some cases (particularly the R.F.G.) almost entirely fill the barrels. An important gain in stowage is obtained by placing 125 lbs. in each barrel, every four barrels containing 500 lbs.

The barrels are made of best Quebec oak, and will be found fully described in Captain Majendie's Treatise on Ammunition, Part I.

Much discussion has arisen as to whether powder barrels are the fittest cases in which to store powder. They certainly present many advantages, though there are some serious drawbacks attending their use, the worst of which is that they cannot keep out damp. But they are cheap and very durable, and when properly hooped and coopered perfectly tight. Their shape also admits of their being moved about by rolling, a decided advantage in magazines where the practice of pushing or dragging anything along the floor is strictly forbidden. But powder placed in barrels and stowed in damp magazines, or on board ship, always suffers from the moisture in the atmosphere and speedily deteriorates. Metal cases are therefore necessary under certain conditions, but for general service the powder barrel answers very well. Not the least of its merits is that it can be unheaded in a few seconds for examination of its contents, and as quickly headed up again. The removal of the entire head admits of a much more thorough examination of the contents of the barrel than would be afforded by opening a small door or lid in the barrel head, such as are made in the heads of gun-ammunition barrels. Various proposals have been made ever since the days of Congreve to line powder barrels with different materials, zinc, lead, leather, india rubber, &c., none of which have been adopted.

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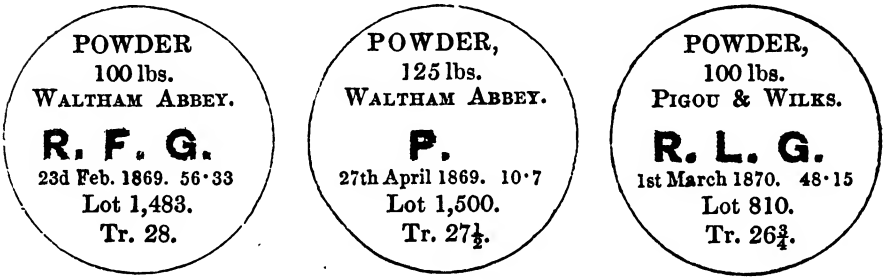
New powder when it leaves the maker's hands for transmission to Purfleet, the great depôt where all new powder is received, is marked as follows, in *seven* lines—

1st line, "*Powder.*"
2nd „ Quantity in barrel.
3rd „ Maker's name.
4th „ Description of powder in RED.
5th „ Date of stoving, number of barrels in stoving, and number of barrel.
6th „ Number of lot.
7th „ *Tare*, or weight of barrel.

A few specimens of actual markings are given underneath to show more fully the meaning of the above. Let the reader observe that at present only the markings of *new* powder, or powder that has never been out of the barrels in which it was first placed, are under consideration.



Specimens of markings of *New* Powder.

The fifth line is the only one which requires explanation. It contains, first, the date of stoving (*e.g.*, as above, 23d February 1869, 27th April 1869, and 1st March 1870); second, the number of barrels in the stoving (56 in the first, 10 in the second, and 48 in the third); and third, the number of the individual barrel; the first barrel is the 33d of the whole 56 stoved; the second is the 7th of the 10 stoved; and the third is the 15th of the 48 stoved.

All powder manufactured at Waltham Abbey as soon as it is proved and marked is transmitted to Purfleet, where it is stored till issued as required. Powder supplied by contractors is delivered at Purfleet also, for proof and examination. This is always carried on by the officers of the Royal Gunpowder Factory. Some of the old contracts being still unfinished, the powder supplied under them undergoes no other firing proof but the old mortar one. Provided it passes that, that is to say, provided it ranges not more than five per cent. less than standard Waltham Abbey powder fired at the same time, and provided it cubes and flashes correctly, and is of the proper colour, and free from dust, it is admitted into the service. All powder, however, supplied under recent contracts must undergo exactly the same proofs as the powder made at Waltham Abbey. The proper appliances for conducting this not being as yet erected at Purfleet, samples of each lot of 100 barrels of the contractor's powder are sent to Waltham for firing proof, and examination as to density there. Ten per cent. only of the barrels are opened, and a half-pound sample taken out of each.

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Powders now in Use.

The powders actually in use in the service are as follows :—

1.—L.G. (or Large Grain).

The old cannon powder, now no longer manufactured. Size, 8 to 16 mesh. A large store of this powder still exists.

2.—F.G. (or Fine Grain).

The old small-arm powder, now no longer manufactured. Size, 16 to 36. Very little of this powder now exists.

3.—R.L.G. (Rifle Large Grain).

The new cannon powder which superseded L.G. on the introduction of rifled guns. Size, 4 to 8 mesh. Highly glazed with blacklead. A large store in existence.

4.—R.F.G. (Rifle Fine Grain).

A powder made with dogwood charcoal, which superseded the old F.G. for small arms on the introduction of rifled small arms. Occurs in two sizes—the older, 16 to 20; the more recent, 12 to 20. A considerable store of the powder exists.

5.—Pistol (formerly called R.A. Medium, and Shell F.G).

A very small-grained powder. Size, 44 to 72 mesh. Only used for filling diaphragm and shrapnel shells, and for the charges of pistols. Some small quantities of it exist.

6.—Pellet.
7.—Pebble. Size, $\frac{4}{8}''$ to $\frac{5}{8}''$.

8 and 9.—K. and L., new descriptions of R.F.G.

Small-arm powders made with dogwood charcoal ; the former intended for use with the small-bore rifles of the Henry class, the latter for the Snider-Enfield arm. The size of the first powder is 20 to 28 mesh ; of the latter, 14 to 20.

The manufacture of the four last descriptions of powders, Nos. 6 to 9, has only recently commenced.

Classification of Powders.

The powders described above, however, occur in various states, and may therefore be variously marked. These can, however, be very easily remembered, and cannot be mistaken, provided the two broad distinctions of *service* and *serviceable* powders be borne in mind.

By *service* powder is meant all descriptions of powder used for firing projectiles, whether from cannon or small arms.

By *serviceable* powder, all powder that is fit to be used for any purpose of the service, such as (1) service powder as above defined, (2) powder for blank charges, and (3) powder for filling shells.

The latter class includes the former, it will be observed.

The new classification of powder applies to all the powders previously enumerated, and had better be mastered before going further. It is as follows :—

Class I.—Service Powder.

This includes all new powder, and all powder which is found on examination to be perfectly uninjured. Also R.L.G. and R.F.G. powders which have undergone redusting, if sufficiently good for the class.

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Class II.—*Blank.*

Powder fit only for exercise, salutes, &c.

Class III.—*Shell.*

Powder more deteriorated than that in Class II., and reserved exclusively for filling shells.

Class IV.—*Doubtful.*

Powder the condition or fitness of which is not known, but which is set apart for examination.

Class V.—Powder condemned for sale.

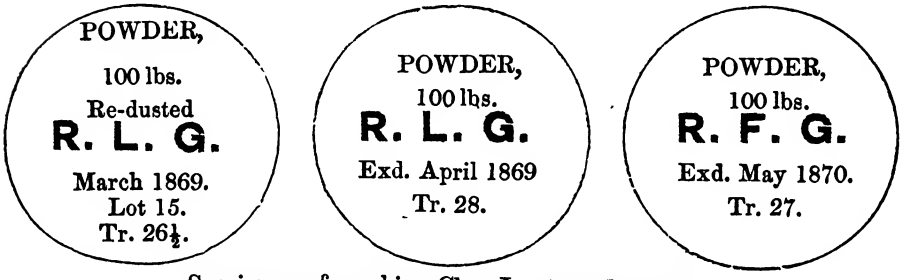
Class VI.—Powder fit only for extraction.

Now Class I. is *service* powder.

Classes I. to III. include all *serviceable* powders.

The markings of these three classes are the only ones that require explanation, for they are the only ones that can be issued for use. Class IV. being "doubtful," that is, powder of which the condition is unknown, must always be reserved for examination. On examination it will of course be distributed into the other classes according to its condition, and if found repairable for any particular class will be marked at once with the class in question, but will have in addition a large cross of *white chalk* across the barrel head, to indicate that it is not fit for issue till the repair has been executed. Powder of Classes V. and VI. will be marked with a similar cross in red to show that they are condemned as *unserviceable.*

Some further remarks on the classification of powders will be made in the concluding chapter. Our present business is with the system of marking. We have already explained the system of marking *new powder*, and have stated that there may be found other powders than newly manufactured ones in the first class. For instance, powder may have been made up into cartridges, and shortly afterwards started and found to be completely uninjured, or R.L.G. or R.F.G. powder may have undergone some slight repair in the way of redusting, and still be sufficiently good to be placed in Class I. All particulars of the maker's names and dates of such powders would, however, be lost. In placing it, therefore, in barrels for service it would be marked just as the new powder formerly described, with this exception, that the lines containing the *maker's names, the date of stoving, and the lot, &c.* would be left out. But in the place of the date of stoving, the date of examination or date of re-dusting would be inserted. The following diagrams show some markings of powder of the description Class I. service powder, but not new powder.



Specimens of marking Class I. returned powder.

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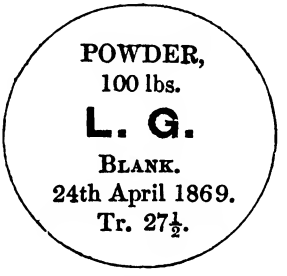
The examples of marking given here and under the head of new powder include all the variations in marking that can be found in Class I. We do not mean all the *various descriptions of powder* previously enumerated that may be found in this class, which may include them all, but all the different ways in which each of these descriptions may be found marked in Class I.

The markings of Classes II. and III. are more simple. They consist in both cases of six (sometimes only five lines) lines only, all in black :—

1st line, "Powder."
2nd „ Quantity in barrel.
3rd „ Description of powder.
4th „ Purpose for which the powder is to be employed.
5th „ A date, generally that of the reduction of the powder to the particular class.
6th „ Tare of barrel.

The following are examples of the style of marking of Classes II. and III. :—



CLASS II.

CLASS III.

Examples of marking Classes II. and III.

The fifth line, that containing the date, is frequently omitted.

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CHAPTER XV.

EXAMINATION AND CLASSIFICATION OF DOUBTFUL POWDER.

CONTENTS.—Powder returned into store as doubtful, examination and classification of.—Nature of the powder generally sent to Purfleet for examination.—Classification of such powder.—Seven classes in which it may be placed.—Examination, how conducted.—Rules to be observed.—Foreign matters present in powder.—Sifting of all powder before returning to store.—Dusty powder, rules for classifying.—General principles to guide examination.

THE examination and classification of powder returned into store at Purfleet as *doubtful, for examination,* forms an important part of the duties of the Royal Gunpowder Factory. In the year 1869 no fewer than 13,550 barrels of returned powder were examined and classified there, the contents of every barrel being inspected. No doubt the number examined in that year was considerably above the average, owing to the large quantity of powder returned from Upnor Castle, the magazines there having been broken up; still the quantity of powder returned into store there every year from the army and navy is very great. Powders in every possible stage are found there; some as good as new; others slightly deteriorated and capable of repair; others in a more dusty and unsatisfactory state; others mixed with sweepings, and fragments of foreign substances; and occasionally some reduced to the condition of paste by the action of water.

The examination and classification of so many varieties and states of powder can only be undertaken by a person thoroughly conversant with the manufacture of gunpowder in all its stages, and who can therefore not only form an opinion rapidly of the present condition of the powder under examination, but of the nature and extent of the repair, if any, which it is capable of standing.

The barrels of powder for examination are taken from the magazines to the examining rooms and unheaded. The examining rooms at Purfleet are capable of holding about 700 barrels, and that quantity can be examined in a day without difficulty. The only examination necessary is that by eye and hand; but in future, in the case of all powder found sufficiently good as regards its physical condition to be placed in Class I. (service), samples will be taken for examination as to density and for firing proof, in order to guarantee that all powder whatever classed as fit for service after a certain date shall be perfectly up to the standard of such powder in all respects.

The greater part of the powder sent for examination to Purfleet consists of L.G. powder started from cartridges; powder of the same description which has been emptied from shells; old powder of the same description which has been stored for many years in foreign magazines; and occasionally powder which has undergone the old process of re-stoving, now abolished. Smaller quantities of R.L.G. powder started from cartridges also occur. With these also are generally found a quantity of started powder, mostly R.F.G. returned

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from Royal Laboratory. Stray barrels of F.G. and the old "Shell F.G.," now called "Pistol," occur now and then, and even small quantities of damaged newer descriptions of powder, such as Pellet and Pebble, from Shoeburyness or the Committees. Mixed with all these are barrels of sweepings from the floors of magazines and powder buildings, and barrels of what may once have been powder, now thoroughly reduced to a wet paste by the action of water.

All such powder must be classed either for *service*, *blank*, or *shell*; or condemned as *unserviceable*. But powder may either be fit to be placed at once in either of the first two classes, or may require a little repair before being classed for them. Again, powder condemned as unserviceable may be *only just bad enough* to be unserviceable, but still saleable as powder for blasting, &c., or again, so *utterly useless as powder*, as to be of no further value except for the saltpetre it contains. These considerations, therefore, necessitate there being two heads under which to class the *service*, the *blank*, and the *condemned* powder.

The total number of classes, therefore, under which doubtful powder of all descriptions may be placed are seven.

Class I. { Service. / Repairable for service.
Class II. { Blank. / Repairable for blank.
Class III. Shell.
Class V. { Condemned for sale.
Class VI. { Condemned for extraction.

The two classes of service and blank powder Nos. I. and II. will not be distinguished by separate *numbers*, but the repairable in each case will have the nature of the repair (which can be only sifting or dusting) marked on it after the number; thus—

I.	I. D.	I. S.
II.	II. D.	II. S.

These marks indicate respectively—

Service.	To be dusted for service.	To be sifted for service.
Blank.	,, for blank.	,, for blank.

Shell powder, being of a worse class than the blank, will not be worth repairing, but if too much broken in the grain and dusty would be condemned as unserviceable.

The examination consists in pouring a quantity of the powder in each barrel from a bowl held some two or three feet above it, and observing the quantity of dust which separates; in examining the contents of the barrel very closely to see if there be any appearance of particles of foreign matter amongst them; and in feeling the condition of the grain as to hardness and crispness. Two rules are constantly observed before coming to a decision as to other matters:

1st. That no powder be condemned for sale unless it be in such a condition as to render it either useless for service purposes, or dangerous to handle in magazines; and,

2nd. That all powder found to contain particles of foreign matters which could not be separated from it, or which would render it dangerous to handle, be at once set apart as condemned for sale.

It is difficult to account for the presence of foreign matters in powder, provided it has been handled with proper care, still such are frequently

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found. To say nothing of scissors, knives, needles, nails, stones, and the like, powder is sometimes found mixed with minute particles of dirt of various kinds, the nature of which is not easily ascertained. On one occasion a percussion cap was found in a quantity of condemned powder which had been sold to one of the government contractors, who was just about to transfer the powder to the stove. Such articles as scissors and needles probably find their way into the powder through the carelessness of the people who make or start the cartridges in which the powder has been placed. To guard against such dangers in future, the new circular on gunpowder provides for the sifting of all powder from broken-up cartridges or emptied from shells *before* being returned into store. The sieves used for the various descriptions of powder are a little larger than the grain, so as to permit it to pass through easily and yet retain any foreign substance.

For	R.L.G.	a sieve of	3	meshes.
„	L.G.	„	6	„
„	R.F.G.	„	8	„
„	F.G.	„	12	„
„	Pistol	„	16	„

Unfortunately, however, no sifting can get rid of minute particles of foreign matter which may yet be very dangerous. If any such, therefore, can be detected or are suspected, the powder should be at once put aside for sale.

Powder which is so dusty that it would find its way through the serge of which cartridges are made is fit for nothing but filling shells. Indeed almost anything is good enough for the purpose, but the presence of a *large* quantity of dust in powder brings it into the dangerous class, for powder of this description will create a large quantity of dust when handled or poured into shells in a magazine, the presence of which on the floors or shelves is very objectionable.

The general principles which must guide the examiner are—

1. All powder that is fit for service must be at once placed in that class, and samples should be taken for firing proof and examination as to density.
2. R.L.G. and R.F.G. powder, if apparently sufficiently good for service *in all respects* except the presence of a little dust, must be marked *repairable for service.* These are the only two classes *that are worth repairing for service.*
3. Powder which does not quite come up to the standard of service, either from slight damage to the grain or the presence of dust, is placed in Class II. for blank.
4. Powder found still dustier than the last requires more careful consideration, for it may either be marked as repairable for the *Blank* Class, if otherwise in good condition, or at once placed in the *Shell* Class. It is on this point that the opinion of a practical gunpowder maker is most valuable. If the powder be not very good in other respects, that is, firm and sound in the grain, the operation of re-dusting would only generate fresh dust in removing that already present. The condition of the powder must therefore be carefully considered, and, if it be in otherwise good condition, and does not contain an excessive quantity of dust, it should be marked *repairable for* II.; if otherwise, it should be placed in Class III.

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5. All powder found too dusty for the former classes, and all powder which has already been in shells, must, unless too greatly deteriorated, be placed in Class III.

6. Powders which are unfit for any service purpose, or which contain particles of foreign substances, but which are yet capable of use as gunpowder for blasting, or such operations, should be marked Class V.

7. All powder the incorporation of which has been thoroughly destroyed, and is either caked into lumps, or in a wet, pasty condition, must be marked Class VI.

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APPENDIX.

No. I.

ARMY CIRCULAR, dated WAR OFFICE, 1st July 1870 (Clause 104 with Appendix).

EXAMINATION, MARKING, AND STORING OF GUNPOWDER.

1. The Secretary of State for War directs that the following instructions respecting the storing, examination, classification, issue, and use of gunpowder, be observed by Officers of the Control Department, Inspectors of Warlike stores, and all other Officers.

Examination and Classification.

2. The examination of gunpowder in store will be conducted by Inspectors of Warlike stores and other Proof Officers, in the following manner:—

3. About one-fifth part of the whole quantity in store will be tested annually; of this fifth, one in every 20 barrels, selected indiscriminately, will be examined. In the second year the same course will be pursued with reference to another fifth of the store, and so on until the whole shall have been examined, when the process will be repeated.

4. The barrels actually examined will in each case be marked, and other barrels will be selected when the same lot again comes under examination.

5. The examination of powder will be confined to an inspection by sight and hand, for the purpose of testing its qualities in the following points:—

1st. As respects the condition of the grain, which should be firm, crisp, and bright in colour;

2nd. As regards freedom from dust and foreign matters.

This latter point will be ascertained by pouring the powder from a bowl held 2 or 3 feet above the barrel.

6. The firing proof, by means of the Eprouvette mortar, will cease.

7. If the examination be in all respects satisfactory, and there be no sign of deterioration, the powder may be placed in Class I.

8. Any portion of *Service* powder found on inspection to be unmistakeably dusty or broken in the grain may at once be reduced to an inferior class.

9. Exceptions to this rule will, however, be made in the case of R. F. G. and R. L. G. powders, which if only dusty will be redusted and restored to the 1st class.

10. In cases that admit of doubt, the report of examination will be transmitted through the local controller to the Superintendent Royal Gunpowder Factory, before the powder is reduced from the Service Class; but if urgently required for service it may be issued.

11. As soon as convenient after the examination of the powder, the Proof Officer will report the result (on W. O. Form No. 1260 or 1261), through the local controller, to the Superintendent, Royal Gunpowder Factory, Waltham Abbey. Form 1260 applies to periodical or occasional examinations of powder in store. Form 1261 applies to the examination of returned powders, provisionally placed in Class IV. as doubtful.

12. *Service* powders include all descriptions used for firing projectiles, whether from cannon or small arms. *Serviceable* powders include service, blank, and shell powders.

13. After examination, gunpowder will be classified and marked according to the following table; and if repaired, the barrels will be specially distin-

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guished (see p. 101), in order to ensure their being issued before gunpowder in a less deteriorated condition. Re-examination will be noted in like manner with date.

Class.	Designation.	Description.
I.	Service - -	1. All new powder. 2. All returned powder (except started powder) which on examination may be found uninjured. In exceptional instances, such as when powder is started from cartridges recently made up and never issued from store, this powder, if found in all respects uninjured, may be placed in Class I.
II.	Blank - -	1. Powder from broken-up cartridges, cannon or small-arm, unless specially placed in Class I.* 2. Service powder found dusty or broken in the grain at periodical inspections, or on return; except in the cases of R. L. G. and R. F. G. powders, which, if only dusty, will be re-dusted for service.
III.	Shell - -	1. Powder found too dusty for Class II. 2. Powder emptied from shells.
IV.	Doubtful - -	All powder whatever (except new powder) returned into store and awaiting examination.
V.	Condemned for sale.	Powder found on examination to be too much deteriorated to be placed in any of the above classes.
VI.	Condemned for extraction.	Powder found to have been so much damaged as to be unfit for any purpose but extraction of saltpetre.

* Powder obtained by breaking up breech-loading small-arm ammunition should be at once thoroughly wetted, as it may contain small particles of detonating composition. In this state it is useless except for extraction of saltpetre, and will therefore be placed in Class VI.

14. Powders found on examination to be repairable, will at once be marked with the class to which they are capable of being converted; but will be crossed in white chalk, in order to indicate that they are only equivalent to a *doubtful powder* in an issuing point of view.

15. At home stations all powder returned into store will, in the first instance, be placed in Class IV., and marked as laid down in paragraph 14, previous to inspection; it will be removed to one of the other five classes on the result of the inspection being determined. At stations where the conveniences for local examination may exist, a requisition will be made by the controller to have this inspection made without delay. If circumstances should render such a course impracticable, the gunpowder will be retained as "*doubtful*," and a report of the circumstances made to the Controller, Royal Arsenal, Woolwich, who will convey the orders of the Controller-in-Chief in the matter.

16. At foreign stations the examination of powder will be conducted by the proof officer, on the requisition of the control officer. The examination will be made as soon as possible after delivery into store, in order to enable the

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Commissary to assume charge of the powder in accordance with its existing state and condition.

17. At stations where no Artillery are located, the Commissary will personally examine all powder contained in the original packages as soon as received into store. If no sign of deterioration present itself, he may assume charge of the powder under its original classification, and may re-issue it accordingly; but should there be any reason for doubt, the powder will be taken in charge and marked as under Class IV., and the circumstances reported to the Controller, Royal Arsenal, Woolwich, who will communicate the order of the Controller-in-Chief.

18. Powder from broken-up cartridges, and powder emptied from shells, will in all cases be sifted *before* being returned into store, so that all extraneous articles may be detected. Barrels of powder "emptied from shells" should be distinguished as such.

19. The sizes of sieves used in sifting powder before returning it into store, will be as follows:—

For R. L. G. powder, a sieve of	3	meshes	to	the	inch.
L. G.	„	„	6	„	„
R. F. G.	„	„	8	„	„
F. G.	„	„	12	„	„
Pistol	„	„	16	„	„

Storing, Uses, and Issue of Powder.

20. On receiving powder, commissaries will look to the distinguishing marks showing the description of powder, maker's name, and dates of stoving; and will arrange the barrels in the magazine accordingly, carefully keeping the powder of each date of stoving together as far as practicable.

21. In issuing service powder, care should be taken to issue, as far as possible, the powder of the same maker, and of the same date of stoving.

22. The annexed examples will show the manner in which the heads of barrels will be marked in future.

No. 1.

POWDER,
100 lbs.
WALTHAM ABBEY.
R. L. G.
23rd Feb. 1869. 56–33.
LOT 1483.
Tr. 28.

No. 2.

POWDER,
100 lbs.
L. G.
Examined 20. 5. 69.
Tr. 27.

No. 3.

POWDER,
100 lbs.
R. L. G.
Redusted* 17. 10. 69.
Tr. 26½.

No. 4.

POWDER,
100 lbs.
L. G.
BLANK.
Tr. 25.

No. 5.

POWDER,
100 lbs.
L. G.
SHELL.
Tr. 28.

* Or "repaired," as the case may be.

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23. No. 1 applies to new powder.
No. 2 applies to returned powder, which, after examination, has been classed for service.
No. 3 applies to returned powder, which, after examination, has been re-dusted or otherwise repaired for service.
No. 4 applies to blank or exercise powder.
No. 5 applies to shell powder.

The 5th line in No. I contains:—

1. The date of stoving, 23rd February 1869.
2. The number of barrels stoved (56).
3. The number of the barrel itself in its stoving (33).

24. Gunpowder is divided into lots for convenience of storing; each of the 100 barrels composing a lot is marked with the same number, and the numbers of the lots run consecutively for each manufacturer, as powder is supplied.

25. The following list shows the purposes for which powders of the several descriptions are to be used; and demands and issues will be regulated in accordance therewith.

Service Pellet. For all charges of 50 lbs. and upwards, including battering charges for 10-inch rifled guns, and all charges of guns of higher calibre.

Service R. L. G. For full charges of 10-inch rifled guns and for all charges of rifled guns of lower calibre, except the 7-pr.; also for all charges for wrought-iron S. B. guns.

Service L. G. For bronze and cast-iron S. B. ordnance.

Service R. F. G. For rifled small-arms of every description except pistols.

Service F. G. For 7-pr. M. L. R. guns, and for all smooth-bore small-arms.

*Service Pistol.** For Colt's, and Dean and Adam's cartridges, and for bursting charges of all shrapnel shells.

Blank, or Exercise R. L. G. and L. G. For blank charges of all descriptions of rifled and smooth-bored ordnance.

Blank, or Exercise R. F. G. and F. G. For blank small-arm cartridges of every description. These powders may, if considered advisable, be used for blank charges for ordnance when there is a surplus store.

Shell Powder. L. G. for the bursting charges of all shells, rifle, or smooth-bore, except shrapnel. F. G. powder is to be used for 6, 9, 12, and 20-pounder segment shells. F. G. or L. G. in Class II. may be taken if no F. G. or L. G. in Class III. be available, and service F. G. or L. G. if no blank F. G. or L. G. be available.

26. *Service* powder will never be issued for *blank* or *exercise* cartridges when any powder classed under the latter head is available. This rule is intended to apply strictly to the non-issue of Service R. L. G. and R. F. G. powders for blank charges. Exercise powder will not be issued for filling shells, when shell powder is available.

27. Occasional opportunities are to be taken at all stations, especially where the magazines are liable to damp, for shifting powder from one bay to another, and opening and re-coopering a few barrels, in order to ascertain if the powder is free from lumps, and to keep the barrels in a serviceable and good state. If in performing this work the powder should be found in any way *lumpy*, or *set*, it will be shifted from one barrel to another, the lumps being broken down with the hand as the powder is passed from the barrel to which it belongs, to the new one.

28. The practice of rolling about barrels must not be resorted to, as it breaks the grains of powder into dust.

29. Whenever it may be necessary to shift gunpowder from one barrel to another, the barrel intended to receive such powder will first have all the marks on it carefully obliterated, and will then be remarked with precisely the same marks as the barrel from whence the power is transferred, with the exception of the tare marks.

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* This powder has hitherto been called "Shell F.G."

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30. Nails should on no account be used to fasten on the hoops in re-heading powder barrels.

31. Barrels should not be placed against the walls of magazines, as the powder is more liable to injury from damp in such situations.

32. The proof officer will be careful to note at his issuing and receiving examinations, the numbers of the lots, as also the marks and dates that have been placed on the various barrels of powder submitted for his inspection, before being issued to, or on being received from, Her Majesty's Land or Naval Forces. All these particulars will be entered in the report made to the Commissary, in order that they may be available for future reference in case of necessity.

Register of the Store of Gunpowder.

33. W. O. Form No. 1259 annexed will supersede W. O. Form 1234. It is intended to show the quantity of each description of powder stored in all the magazines at home and abroad; the condition and capacity of the magazine, and whether in charge of a Commissary, or of the Commanding Officer Royal Artillery. This return will be compiled very carefully, and transmitted half-yearly to the Controller, Royal Arsenal, Woolwich, for the information of the Controller-in-Chief.

Report of Examination of Gunpowder.

34. W. O. Form 1260 annexed, will replace W. O. Form 1218. It will be filled in by the proof officer after the completion of the annual examination of the powder in the district. W. O. Form 1261 will in like manner be filled in after the examination of doubtful powder. These returns will then be forwarded immediately, through the local Controller, to the Superintendent, Royal Gunpowder Factory, Waltham Abbey.

35. Expenditure returns of powder will be made up half-yearly according to the forms annexed. W. O. Form 1262 is applicable to land service, and W. O. Form 1263 to sea service. The returns will be forwarded through the proper channels for transmission to the Controller, Royal Arsenal, Woolwich; in order to enable him to compile a general statement for the information of the Secretary of State for War.

36. War Office Circulars 512, 541, 674, 892, 920, are hereby cancelled.

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Forms to accompany the foregoing Circular.

No. 1.

Station _____

Date _____

HALF-YEARLY RETURN of the Gunpowder at this Place, showing also the State and Capacity of the Magazines.

Nature of Gunpowder in Store.			In Store per last Return.	Since received.	Since issued.	In Store at this Date.	Remarks.
Service, Class I.	F. G.	lbs.					
	L. G.	"					
	Pellet	"					
	Pistol	"					
	R. F. G.	"					
	R. L. G.	"					
Blank, Class II.	F. G. and R. F. G.	"					
	L. G. and R. L. G.	"					
Shell, Class III.	F. G. of Sorts	"					
	L. G. of Sorts	"					
Doubtful, Class IV. of Sorts		"					
Unserviceable	Class V. of Sorts	"					
	Class VI. of Sorts	"					
Repairable	F. G.	"					
	L. G.	"					
	R. F. G.	"					
	R. L. G.	"					
Miscellaneous	Dust, foreign, meal, pit-coal, &c. as per detail in column of Remarks	"					
Total loose powder							
Made up into cartridges.	Cannon L. G.	"					
	Cannon Pellet	"					
	Cannon R. L. G.	"					
	F. G., R. F. G., and Pistol, Small-arm, Bursters, &c.	"					
Grand Total							

Controller,
Royal Arsenal,
Woolwich.

Signature _____

The Controller-in-Chief, Pall Mall.

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No. 2.

W. O. Form 1259.

CAPACITY of MAGAZINES, and Distribution of Space estimated in whole Barrels.

Denomination of Magazines.	Authorised Capacity of each in whole Barrels.	Space occupied by Gun-powder, Loose and in Cartridges.	Space lost in Stowage, through Damp or other Causes, or unavailable for Reasons given in Column of Remarks.	Space available for the immediate reception of Powder.	State of Repair.	Remarks.

Signature _____

Officers in charge of magazines are enjoined to be particularly careful in the preparation of this Return.

In the first page the charge will be represented in lbs., and must correspond with the Station Ledger *Remain;* and in the second, the space is to be calculated in *whole* barrels of 100 lbs. each.

It will be understood that the column for available room in each magazine is to be strictly confined to such space *only* as may be suitable and ready for the immediate reception of powder without obstacle of any kind.

All space which cannot be *immediately* appropriated as above will be transferred to the column of *space lost.* The dates of authority, with explanatory particulars, will be detailed in the "*Remarks.*"

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No. 3.

W. O. Form 1260.

PERIODICAL OR OCCASIONAL

REPORT

OF THE

EXAMINATION OF GUNPOWDER

In charge of_____

at_____

*Date*_____

The Controller at_____

For the Superintendent,
Royal Gunpowder Factory,
Waltham Abbey.

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REPORT of the Examination of Gunpowder in charge of _____ at _____.

Date _____.

Description.					Date of Receipt at the Station.	No. of Barrels remaining.	Stoving Numbers on Barrels opened for Examination.	Report of Examination.	Placed in Class.
Maker's Name.	Date of Stoving.	No. of Barrels in Stoving.	No. of Lot.	Sort of Grain.					

The Controller at _____

For Superintendent, Royal Gunpowder Factory, Waltham Abbey.

_____

Proof Officer.

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No. 4.

W. O. Form 1261.

REPORT

OF THE

EXAMINATION OF DOUBTFUL GUNPOWDER

at_____

*Date*_____

The Controller at_____

For the Superintendent,
Royal Gunpowder Factory,
Waltham Abbey.

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REPORT of the Examination of Doubtful Gunpowder at _____.

Date _____.

Description.				Returned from	No. of Barrels examined.	Result of Examination.	——
Maker's Name.	Date of Stoving.	No. of Lot.	Sort of Grain.				

The Controller, Woolwich.

For Superintendent, Royal Gunpowder Factory, Waltham Abbey.

Controller. *Proof Officer.*

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No. 5. W. O. Form 1262.

Powder Expenditure.—Land Service.

Return of the Quantity of Gunpowder of all kinds expended in the _____ District or Command during the Half-year ending _____ 18___.

_____ Station. _____ Date.

——	Service.						Blank.		Shell.		Total.
	Pellet.	R.L.G.	L.G.	R.F.G.	F.G.	Pistol.	R.L.G. L.G.	R.F.G. F.G.	L.G.	F.G.	
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Royal Artillery - - -											
Militia and Yeomanry - -											
Volunteers - - -											

Where quantity of powder in lbs. is not known, the number of rounds expended and nature of cartridge, &c., should be stated.

The Deputy Adjutant-General,
Royal Artillery, Horse Guards.

_____ *Commanding.*

For transmission to
The Controller,
Royal Arsenal, Woolwich.

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No. 6. W. O. Form 1263.

POWDER EXPENDITURE.—SEA SERVICE.

RETURN of the Quantity of Gunpowder of all kinds received into Store and expended by H. M. _____
during the Half-year ending _____ 18___.

_____ Date. _____ Station.

———	Service.						Blank.		Shell.	Total.
	Pellet.	R.L.G.	L.G.	R.F.G.	F.G.	Pistol.	R.L.G. L.G.	R.F.G. F.G.		
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
In store as per last Return, dated - Since received - - - -										
Total - -										
Expended during half year ended - -										
In store at present date - -										

This Return is invariably to be compiled every half year, or when "paid off." If no expenditure, &c., the word "Nil" to be written across the Form.

Where quantity of powder in lbs. is not known, the number of rounds expended and nature of cartridge, &c., should be stated.

The Secretary to the Admiralty,
For transmission to
The Controller,
Royal Arsenal, Woolwich.

_____

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No. II.

Sketch of the General Regulations for the Prevention of Accidents in force at the Royal Gunpowder Factory.

The regulations against accident may be divided into two broad classes, viz.

A. Those intended as precautions against accidents arising.

B. Those intended to guard against its spread, supposing such to have arisen.

The first named may be subdivided under two heads, viz. :

I. General rules applicable to the whole factory.

II. Particular rules, in addition to the above, enforced in the various departments of the factory.

A.

I. General Rules.

1. Smoking in all parts of the factory is strictly prohibited. No tobacco pipes, or lights of any description, are allowed to be taken inside any part of the factory grounds. For this purpose a notice board is put up at each gate; and the police in charge of the gates have strict orders to satisfy themselves (if necessary by special search) that no person, whether a workman or a stranger, going into the factory has any lucifer matches, cigar lights, &c. about his person.

2. Particular care is taken that no person in a state of intoxication is admitted.

The workmen (both the day and the night labourers) are very closely watched when entering the gates to go to their work.

3. The men are cautioned against carrying knives, keys, or articles of iron or steel, about with them in their pockets.

4. No workman is allowed to enter any house or building in which powder is worked before putting off his outer clothes, and putting on a working dress and magazine shoes. The dress is made of incombustible material, and without pockets; and the shoes are made entirely of leather fastened with wooden pegs, and without metal nails of any description. These shoes are never allowed to touch anything but the floors of the powder buildings themselves, and are never to be worn except in them. Should they be taken out of a building they are carried in the hand and hung up on a nail, or placed on a clean shelf. The men are also specially provided with leather caps and gloves, both furnished with flaps to protect the neck and wrists.

5. The strictest orders are given that the floors of all buildings, platforms, boats, &c. are to be kept perfectly clean and free from the slightest trace of gravel, sand, or grit. As a rule, powder which has fallen on the floor is not allowed to be mixed with the powder under operation. All such powder is swept up, and reserved for extraction.

6. The implements used in the various processes are made of copper or wood.

7. No repairs to the machinery or buildings are permitted till both have been thoroughly washed out with water.

8. No powder barrel, charge tub, or vessel containing powder, or used in a house where powder is under operation, is allowed to be dragged or pushed along the floor. Barrels or charge tubs are always rolled on their edge, with as little friction as possible.

9. In all cases when a thunderstorm approaches the workmen are instructed to stop the machinery, close the buildings, and leave them till the storm has passed over.

10. Every article of metal employed in the structure of the buildings, particularly the nails used in the flooring, the hinges, and handles of doors, or windows, is of copper or gun metal.

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If it be necessary in any case for additional strength to use iron, the metal is covered up with thick leather, or sheet lead. This rule is rigidly observed also in the construction of barges, boats, or carts of any description used for the conveyance of powder.

11. Every building is provided with a complete and thorough system of lightning conductors.

12. All bridges under which boats conveying powder in any stage of manufacture, or refined ingredients, may pass are constructed in such a way that no fragment of gravel, or gritty particles can drop into boats when passing under them.

13. The machinery of all kinds is specially constructed with a view to carry on all the processes with the least possible amount of friction; all parts of machinery that can be made of copper or gun metal are made of these materials, and when iron is unavoidably used the metal is covered over with leather, or sheet lead. Improvements are constantly being made to the machinery from time to time, as experience suggests, to lessen the risk of accident. It is impossible to give anything but the briefest sketch of the principles on which the extensive machinery at Waltham Abbey is constructed, and which can only be understood by study and inspection of the machines themselves.

14. The floor of every building in which gunpowder is handled or stored is completely covered with thick leather hides, fastened down with copper nails, and no gritty or gravelly particles, or fragments of iron are ever permitted to touch them.

II. Particular Rules observed, in addition to the above, in various Departments of the Factory.

I. *In the Saltpetre Refinery.*

a. Careful precautions are taken against the chance admission of any particle of gravel, sand, or grit into the refined saltpetre.

b. Similar precautions are taken that when damaged powder, or powder sweepings are sent to the refinery to have the saltpetre extracted, the material is very carefully and thoroughly wetted throughout before being handled or temporarily stored.

II. and III. *In the Charcoal House and Sulphur Refinery.*

The same rigid precautions against accidental admission of gritty particles into the refined ingredients are enforced.

IV. *In the Mixing Houses.*

a. Ground charcoal is not allowed to remain in the mixing house overnight, in case of spontaneous combustion.

b. No mixed charges are allowed to be kept in the buildings overnight.

V. *In the Incorporating Mills.*

a. The millmen are not allowed to enter the mills when the machinery is in motion, unless properly protected by incombustible clothing, and with their caps and gloves properly fastened.

b. When a fresh charge of 50 lbs. of the mixed ingredients is put in the mill-bed, particular care is taken that the portion of the old charge left under the runners is removed, broken up, and mixed with the fresh charge before the incorporation is commenced.

c. The greatest care is observed that no portion of the machinery of the mill (such as a bolt, drip-pan, &c.) becomes loose and drops into the charge.

d. The mill runners are never moved off powder on to leathers unless under the presence and supervision of the foreman of mills.

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VI. *In the Breaking-down, Press, and Granulating Houses.*

No workman is allowed to remain in these buildings after the machinery is started, but the foremen are permitted to enter them from time to time to see that the machinery is working properly.

VII. *In the Dusting Houses.*

Extra care is taken in these houses to keep the powder dust from accumulating on the floors.

VIII. *In the Stoves.*

The boilers and pipes are so arranged that there is no possibility of accident arising from over-heating.

IX. *In the Barges and Boats used for the Transport of semi-manufactured and finished Powder.*

a. All boats used for conveying powder or refined ingredients are kept as scrupulously clean and free from gritty or sandy particles as the powder buildings themselves.

b. Leather hides are always used to place the powder barrels on when embarking or loading powder.

c. No powder is conveyed in an open boat unless the barrels be carefully covered with tarpaulins or wadmiltilts.

d. Men employed in the boats are not allowed to enter them unless in working dress, and before entering them must put on the magazine shoes provided for each boat.

e. In landing powder from barges and boats the leather-covered platform of the magazines or buildings is previously damped.

f. No leaky or badly-coopered powder barrel is allowed to be embarked on any account.

g. Men at work in the barges wear magazine shoes and clothing.

B.

The regulations intended to provide against the spread of disaster should an accident have already happened, comprise restrictions as to the quantities of gunpowder operated upon at any one time in the various houses, the construction of the buildings, distances apart at which they are placed, and the erection of intervening obstacles.

Under this head also are included precautions against the transport of powder or explosive material near buildings in which manufacture is proceeding.

1. The quantities of powder kept in any one building and operated upon at one time are restricted according to the nature of the process of manufacture. Thus, in the mixing house the quantity of mixed material is limited to 600 lbs.; in each incorporating mill the charge operated upon is limited to 50 lbs.; in each breaking-down house 1,000 lbs.; in each press house 900 lbs.; in each granulating house 1,500 lbs.; in each stove 5,600 lbs.

These quantities are generally less than the lowest limits fixed by the existing Gunpowder Act, 23 & 24 Vict., cap. 139.

This Act provides for no greater quantity than 1,120 lbs. being pressed at one time in each press house, nor more than 1,344 lbs. granulated in each granulating house; but the Act sanctions double these quantities being within the respective houses at the same time.

2. Powder buildings are constructed either of the lightest materials, so as to offer the least possible resistance to explosion within, and lessen as far as possible the projectile force and destructive effect of fragments of the building exploded, or they are built so as to offer resistance to impact from without. In the first category are those buildings in which powder is operated upon, and in the second those used either as temporary or permanent storehouses for powder, or material in an explosive state.

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3. Buildings in which powder is worked are generally placed at distances of from 150 to 200 yards apart. No absolute rule is laid down, as a great deal depends upon the conformation of the ground, but for houses in which the quantities do not exceed those stated above, those distances are considered to be sufficient.

4. To prevent the spread of an explosion and lessen its violence on neighbouring houses, each building is planted round with trees, where practicable, or is partly enclosed by lofty substantial traverses of brickwork.

5. The grand magazine at Waltham Abbey, constructed for 1,200 barrels of powder (but from which finished powder is generally removed weekly to the great store depôt at Purfleet), is distant 260 yards from the nearest powder building, a heading-up house rarely used, and 350 yards from the next nearest, a granulating house.

6. A considerable number of expense magazines, strongly built of brickwork with splinter-proof arched roofs, are placed at convenient distances over the factory.

These magazines are provided to guard against the accumulation of material in any of the powder houses, and no powder is allowed to be kept at night anywhere but in one of them.

7. Splinter-proof boat houses are erected at convenient places on the mill head, in which boats laden with semi-manufactured powder may lie if they are prevented from delivering their charge by any temporary stoppage at the building to which they are proceeding. Thus should a building explode, this precaution may prevent the explosion from communicating with boat loads of powder, which in their turn might extend it to more distant buildings.

8. In the incorporating mills, where accidents from time to time may be expected, a drenching apparatus is erected, which is brought into action when an explosion occurs in one mill. Should this occur all the charges under incorporation at the adjacent mills are drenched at the time.

9. A danger signal is always shown when an incorporating mill or any other powder building is working, and no boat or truck containing powder is suffered to approach the mill till the machinery is stopped.

10. Special care is taken that all workmen employed in the factory are made familiar with the precautions necessary to be observed.

Every man is ordered to make himself thoroughly conversant with the general rules, and the foremen of all houses are ordered to read the regulations (a copy of which is hung up in every house) over to their men once every week.

No workman is put upon powder work until he has served a certain time in the factory, and thus had many opportunities of making himself familiar with all the precautions used in the manufacture, handling, and storage of gunpowder.

11. Nine fire engines are always maintained in immediate readiness in the factory, distributed among the buildings, and in situations likely to be of service, and promptly available in case of a building or wood-stack taking fire.

The workmen are told off in squads to these engines, and are regularly drilled at their use, so that in the event of a fire or explosion every man knows his place and duty.

12. A police force, consisting of one inspector, two sergeants, and 12 constables, is attached to the factory from the Metropolitan District.

All parts of the factory grounds are patrolled day and night, to guard against the entrance of unauthorised persons, give immediate notice, and assistance in the event of an accident happening.

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No. III.

BRIEF ABSTRACT of the Acts 23 & 24 Vict. cap. 139 (28th August 1860), and 24 & 25 Vict. cap. 130 (6th July 1861), passed to amend the law concerning the making, keeping, and carriage of Gunpowder and compositions of an explosive nature, &c.

23 & 24 Vict. cap. 139.

Clause I. repeals the former Acts on the subject, viz.:

The 9 & 10 W. III. c. 7.
5 G. II. c. 12 (1).
and 12 G. III. c. 61.

Clause II. contains the regulations to be observed with regard to the manufacture and keeping of gunpowder.

a. The manufacture is only to be carried on in places licensed for the purpose.

b. Not more than 50 lbs. of gunpowder or materials to be made into gunpowder, as regards sporting and Government powder, to be worked under one pair of millstones, rollers, or runners, at one time; and not more than 60 lbs. as respects all inferior powders.

Every incorporating mill, or group of incorporating mills, to be provided with a charge house for the store of mill charges, properly constructed of stone or brick, and situated at a safe and suitable distance.

c. The quantity of gunpowder to be subjected to pressure at one time in any press house not to exceed 10 cwt. (1,120 lbs.)

d. The quantity of gunpowder to be corned or granulated at one time in any corning or granulating house not to exceed 12 cwt. (1,344 lbs.)

e. The quantity of gunpowder to be dried at one time in one stove not to exceed 50 cwt. (5,600 lbs.)

f. The respective quantities to be at any one time in any press house, or corning or granulating house, not to exceed twice the quantities allowed to be pressed or granulated at once.

The quantity of gunpowder to be at any one time in any drying house or dusting house not to exceed what is necessary for the immediate supply and work of such house; and for the purposes of this provision any building used with any such press house, corning or granulating house, drying house, or dusting house, shall be deemed part thereof save only magazines constructed with stone or brick, and situated 40 yards at least from every such house as aforesaid (*i.e.* expense magazines), and save only the stove in which the powder which has been dried may be cooling.

g. Every maker of gunpowder to have (in addition to expense magazines) for the safe keeping of all finished gunpowder, a good and sufficient magazine, distant at least 140 yards from any house or place used for or in the making of gunpowder; such magazine to be well and substantially built of brick or stone, and situated in such places as may have been lawfully used or duly licensed by justices before the commencement of this Act, or may be licensed as herein-after mentioned, and to be distinguished as a store magazine.

h. Every maker of gunpowder to cause, with all due diligence, all finished gunpowder made by him to be removed to the store magazine, built and situated as above.

i. Every maker of gunpowder to provide his store magazine with good and sufficient lightning conductors in connexion therewith.

Clause III. reserves power to the Secretary of State, on application and sufficient cause shown, and after inspection by any person he may think fit to report thereon, to sanction the erection (or continuance, if erected before the passing of this Act) of expense magazines within the prescribed distance of 40 yards from any powder house, and of store magazines within 140. The use and continuance of any magazine to be lawful pending an application to the Secretary of State, and until the expiration of a time fixed for its removal.

Clause IV. enacts: 1st. That all gunpowder made in any place where under the Act it is not lawful to make it, and all gunpowder found in any of the houses of a factory in excess of the quantities fixed as lawful to be in such houses by clause II. shall be forfeited.

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2ndly. That any person making gunpowder, or causing it to be made, contrary to this Act, or keeping, or causing to be kept, in any powder house gunpowder contrary to the foregoing provisions, shall for so doing, in addition to the forfeiture aforesaid, forfeit for every such offence any sum not exceeding 2*s.* for every pound of gunpowder forfeited.

3rdly. That every person making gunpowder without having a store magazine distant 140 yards from any mill or powder house shall forfeit a sum not exceeding 25*l.* for every month he continues the manufacture without having such a magazine; and

4thly. That every gunpowder maker who wilfully neglects or delays to remove with due diligence his finished powder from the powder houses in which it is made, or from the expense magazines used therewith, to the store magazine distant as aforesaid, shall forfeit for every day the offence continues any sum not exceeding 5*l.*

Clause V. enacts: 1st. That no charcoal is to be kept within 20 yards of any mill or engine used for making gunpowder, or of any powder house or expense magazine belonging thereto; and 2ndly. That any gunpowder maker who acts contrary to this enactment shall forfeit for so doing any sum not exceeding 5*l.*, and any sum not exceeding 5*l.* for every week he continues to do so.

Clause VI. relates entirely to the manufacture of percussion-caps, ammunition, fireworks, &c.

Clause VII. enacts the penalties for violation of the provisions of Clause VI.

Clause VIII. relates exclusively to the sale of fireworks; and Clause IX. to the penalty for throwing fireworks in thoroughfares.

Clause X. gives power to justices of the peace, on application, to license the erection of new buildings to be used in the manufacture of gunpowder, with magazines near thereto; and also the erection or use of magazines to contain unlimited quantities of gunpowder in places not within London or Westminster, or other limits herein-after described (see Clause XVIII.).

Clause XI. permits justices of the peace, on application, to license similar places for making and keeping percussion-caps, ammunition, &c., &c.

Clause XII. provides that every person making application for such licenses must give notice in writing of his intention to apply, and of the places proposed, fourteen days before making it; if in England to an overseer or churchwarden of the parish in which they lie; if in Scotland, to the schoolmaster or session-clerk; and, if in Ireland, to the clerk of the Union; and must, moreover cause the said notice to be affixed to the door of every church and chapel in the parish, previous to the commencement of Divine Service on a Sunday, ten days at least before making his application.

Clause XIII. reserves to the justices the power of making their license of such places conditional on such precautionary measures as they may deem proper to diminish the risk of danger to life by explosions being taken and maintained with regard to the structural arrangement of such houses, the erection of mounds or screens to separate the same from any inhabited house or otherwise.

Clause XIV. permits an applicant, should the justices either refuse his application, or grant the same under conditions which he may deem unsatisfactory, to require them to certify such refusal to him in writing, to be signed by the chairman presiding, with the grounds thereof, and within 10 days from the delivery thereof to transmit the same to one of Her Majesty's principal Secretaries of State, with a memorial praying that a license may be granted to him notwithstanding, or that the conditions imposed may be modified as he shall set forth, and authorises the Secretary of State either at once, or if he shall think fit, after inquiry and report by such person as he may appoint, to grant the license either absolutely, or with conditions, or to alter or modify the conditions imposed by the justices.

Clause XV. permits owners or occupiers of gunpowder manufactories (and owners or occupiers of buildings used for the making of percussion caps, fireworks, &c.) to make such rules as they may think fit, and to alter them from time to time, for the prevention of accident, provided such rules be not repugnant to the laws of the kingdom or the provisions of this Act; such rules to be signed by each owner or occupier, and a copy to be delivered to every servant or workman employed, and a copy to be affixed in every building used for such purposes.

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Clause XVI. enacts that any servant or workman who violates such rules, or who does or attempts to do anything tending to cause explosion shall be subject to a penalty not exceeding 5*l.*, on summary conviction before any justice of the peace in England, or any sheriff, justice of the peace, or magistrate in Scotland; and that any such servant or workman may be apprehended without a warrant, removed from the premises, and conveyed at once before a justice, sheriff, or magistrate, who shall proceed with all convenient despatch to hear and determine the complaint against him.

Clause XVII. authorises any of Her Majesty's principal Secretaries of State to commission any person he may think fit to inspect, examine, and report upon any building, magazine, or place used in the making or keeping of explosive substances; such person to have free access to such at all reasonable times without giving previous notice, and owners or occupiers of such places to furnish the means necessary for such entry, inspection, and examination, under a penalty of 5*l.* for any wilful obstruction.

Clause XVIII. lays down the quantities of gunpowder which may be kept at one time by persons other than manufacturers.

A dealer in gunpowder, or maker of cartridges, fireworks, or rockets, may keep not more than 200 lbs., and any person not being such dealer may keep not more than 50 lbs. in any building or place, or on any river or other water (with the exceptions specified beneath), if not within the following limits, being the limits within which gunpowder mills or magazines may not be licensed under this Act, viz.:—

1st. Within London or Westminster, or within three miles of either of them.
2nd. Within any borough or market town, or one mile of the same.
3rd. Within two miles of any palace or house of residence of Her Majesty, her heirs, or successors.
4th. Within two miles of any gunpowder magazine belonging to the Crown.
5th. Within half a mile of any parish church; or,
6th. In any place beyond the limits aforesaid, except—

a. Buildings with magazines belonging thereto, and places lawfully used at the commencement of this Act for the making of gunpowder.
b. Magazines in which greater or unlimited quantities of gunpowder may be lawfully kept at the commencement of this Act; and,
c. Places where it shall be lawful to make gunpowder, or to keep greater or unlimited quantities of gunpowder under the provisions of this Act.

From the above regulations is exempted—

First. Gunpowder in carriages loading or unloading, or passing on land.
Second. Gunpowder in ships, boats, or vessels, loading or unloading, or passing on any river or other water, or detained there by tide or bad weather.

For the purpose of the above enactments all buildings and places adjoining each other, and occupied together, are to be deemed one house or place.

Clause XIX. permits persons to keep at one time, if exclusively for the use of any mine, quarry, or colliery, in any magazine or warehouse (provided such be within 200 yards thereof, and not within 200 yards of any inhabited house, unless erected and used before the passing of this Act, or unless under the written consent of the occupier of the house) any quantity of gunpowder not exceeding 300 lbs. weight; or any quantity not exceeding 4,000 lbs. weight, if kept in a magazine well and substantially built of brick or stone, within 200 yards distance; and if not within any of the limits laid down in the preceding clause, nor within 200 yards of any inhabited house without the written consent of the occupier, and save when continued or erected under a certificate of the Secretary of State, on application and memorial from the owners, lessees, or occupiers of the mine, quarry, or colliery in question.

Clause XX. defines the quantities of gunpowder which may be conveyed by land or water at one time, the nature of the boxes or cases in which it must be placed, the coverings which must be put over it, and the penalties for contravening the above.

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Not more than 30 barrels of gunpowder to be conveyed by land in any waggon, cart, or other carriage, except—

1st. In a van specially made for the purpose, enclosed on every side with wood, in which 40 barrels may be carried; and,
2nd. Except in a railway carriage made for the purpose, in which 100 barrels may be carried.

By water not more than 500 barrels may be carried at one time within the United Kingdom in any barge, boat, or other vessel, except in vessels with gunpowder imported from or to be exported to any place beyond the sea, or going coastwise.

All gunpowder being conveyed by land or water (except in the case of the vessels just specified) must be either—

1st. In barrels, close joined and hooped; or,
2nd. In cases or canisters of copper, zinc, or tin, enclosed in wooden boxes or barrels, without any iron about them, and so secured that none of the gunpowder can be scattered in the passage.

Each barrel or receptacle shall contain no more than 100 lbs. of gunpowder.

Each carriage used for the conveyance of gunpowder on land to have a complete covering of wood, painted cloth, tarpaulin, or wadmiltilt over all the powder therein contained.

Every barge, boat, or other vessel (except the vessels for import, &c. previously specified) used for the conveyance, must have a close deck, and as soon as any gunpowder is put on board such vessels it must be covered with raw hides or tarpaulins.

Should the above enactments be contravened, any person searching under a warrant of a justice of the peace, sheriff, or magistrate, may, under the authority conveyed in that warrant, seize, remove, and detain the gunpowder and barrels or other receptacles in which it is placed, and may for that purpose make use of, during the space of 24 hours, and on payment for the use thereof, any tackling, beasts, or accoutrements belonging thereto.

Clause XXI. orders that if any stale, condemned, or returned gunpowder be brought by any barge, boat, or vessel to any quay or wharf to be landed, no person shall bring any other gunpowder to the place with the intention of loading it till all the former has been unloaded and carried away, and that after the unloading and carrying away no person shall begin to load, or bring with intent to load, any greater quantity of other gunpowder than what was unloaded and carried away, on pain of forfeiting the same.

Clause XXII. enacts that anyone in charge of barges, boats, or vessels (excepting always the vessels specified in Clause XX., for export, import, or going coastwise) loaded with gunpowder, or anyone on board the same who brings, has, or uses, or suffers anyone to bring, have, or use any charcoal, lucifer matches, or other combustible matter, or fire, or lighted candle during the time of loading or unloading, or when the hatches are open; or who smokes, or wittingly allows anyone else to smoke on board such vessels, shall for every offence forfeit any sum not exceeding *5l.*

Clause XXIII. guards against undue delay in loading or unloading gunpowder:

1st. No one in charge of land conveyances must after beginning to load or unload gunpowder, either stay at the place where such is carried on, or suffer any delay in the loading or unloading more than, with the use of all diligence, shall be necessary.

2nd. No one in charge of water conveyances (excepting always the vessels exempted in Clause XX.) under the same circumstances to delay longer than 18 hours unless hindered by the weather.

Clause XXIV. states that the above provisions are not to apply to conveyances, whether land or sea, unless they convey a larger quantity than 100 lbs. weight.

Clause XXV. authorises justices of the peace, sheriffs, or magistrates to issue warrants to search any place within the limits of their jurisdiction, where it is suspected that gunpowder is made, kept, or carried contrary to this Act, and to seize, remove, and detain the same (see Clause XX.); and enacts that the recompense to be paid for the use of the tackling, beasts, or accoutrements

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belonging thereto, made use of to remove the gunpowder, shall be settled by the justices, &c. before whom the complaint shall be heard after the seizure, and shall be recoverable if not paid, as the other pecuniary penalties under the Act; and that the powder may be lawfully detained till it is adjudged whether the same be forfeited, the seizer not to be liable for detention, nor for any loss or damage to the powder, except what is caused by the wilful act or neglect of himself or the persons he employs, and provided that the proceedings for the forfeiture be commenced within 28 days after seizure.

Clause XXVI. states that, except for the Queen's service, not more than 25 lbs of gunpowder is to be on board any ship in the River Thames above Blackwall; the penalty for non-observance of this regulation to be the forfeiture of all the gunpowder found on board above 25 lbs., and the barrels or receptacles in which it is, and of a fine not exceeding 2*s.* for every pound above the 25 lbs. allowed.

Clause XXVII. permits the Conservators of the Thames to appoint persons to search ships, and seize and detain powder.

Clause XXVIII. states that penalties or forfeitures under the Act may be enforced on summary conviction, and contains rules for the disposal thereof.

Clause XXIX. gives the same power to the Lord Lieutenant of Ireland, as to a Secretary of State for the purposes of this Act.

Clause XXX. exempts from the provisions of this Act all buildings or Crown lands, and all such used for the service of the Crown; and states that the Act shall not hinder—

1st, the trial of gunpowder by Her Majesty's officers for the service of the Crown;
2nd, the keeping of gunpowder at the magazines at Barking Creek Mouth in Essex, and Erith Level in Kent; or at the City of Bristol; or in the vessel moored in the River Mersey;
3rd, the carriage of gunpowder to or from Crown magazines under a special and express order of the Secretary of State for War, containing the quantity of powder so carried and the time for which the order shall be in force; or the carriage of gunpowder with forces on their march; or with the militia or volunteer forces during their exercise, or which shall be sent for their use.

Clause XXXI. states further that the Act is not to affect the explosive substances on board Her Majesty's ships, &c.; and that it does not repeal or alter the Act 54 Geo. III. c. 159.

Clause XXXII. exempts from the provisions of the Act the proof houses for gun barrels under 18 & 19 Vict., cap. cxlviii., or in magazines in connexion therewith, unless the quantity of powder kept at one time in any one such proof house and magazine connected therewith exceeds 5 cwt.

Clause XXXIII. exempts also from the provisions of the Act persons conveying unlimited quantities of gunpowder in close decked vessels (as described in Clause XX.) to or from ships lying below Blackwall, from or to magazines situated below Blackwall; or to or from ships in the Mersey, from or to the floating magazines lying there.

Clauses XXXIV. and XXXV. state that the Act does not repeal or affect the provisions concerning gunpowder in or near the London Docks, laid down in sections 134 and 135 of 9th Geo. IV., cap. 116 (local and personal); nor the regulations of any General or Local Police Act.

Clause XXXVI. states that the powers conveyed by the Acts 2 & 3 Vict. cap. 47 (for further improving the Metropolitan Police) and 9 & 10 Vict. c. 25 (for preventing malicious injuries to persons or property by fire or explosive or destructive substances) are to be construed as if this Act were referred to, and not the Act 12 Geo. III. c. 61. repealed hereby.

Clause XXXVII. states that the term borough in the Act shall mean and include—

1. In England, any place for the time being subject to 5 & 6 Will. IV. c. 76.
2. In Scotland, any Royal burgh, and any burgh or town returning or contributing to return members to Parliament; and
3. In Ireland, any place for the time being subject to 3 & 4 Vict. c. 108.

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II.—24 & 25 Vict. cap. 130.

(6th July 1861.)

Clause I. transfers the power of granting licenses under the last Act from the justices of the peace at quarter sessions, to the justices in petty sessions.

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